Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A381
R31AC
Cop. 2

ARS-71-10
NOVEMBER 1957

FIBER SHIPPING CONTAINERS FROM SUGARCANE BAGASSE

LIBRARY
CURRENT SERIAL RECORD
★ MAR 31 1958
U.S. DEPARTMENT OF AGRICULTURE

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

Cover stock and paper on which this publication is printed are made from sugarcane bagasse. The front cover is experimental corrugating board containing 85 percent of fiber from Florida sugarcane bagasse. The back cover is experimental liner board containing 50 percent of fiber from Hawaiian bagasse. The text is printed on a commercial 50-pound (25 x 38) paper containing 90 percent of bagasse fiber processed in the United States.

FIBER SHIPPING CONTAINERS FROM SUGARCANE BAGASSE

E. C. Lathrop, S. I. Aronovsky, S. B. Knapp, F. W. O'Neil,

R. G. Hitchings, A. J. Ernst, and T. F. Clark

This publication was prepared by the
Northern Utilization Research and Development Division
Peoria, Illinois

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

November 1957

The Northern Utilization Research and Development Division, Peoria, Ill., under the administration of the Agricultural Research Service of the U. S. Department of Agriculture, is one of the four large research laboratories established by the Department under the authority of the Agricultural Adjustment Act of 1938. At its inception the name of this laboratory was Northern Regional Research Laboratory.

The function of the several regional laboratories is to conduct chemical, chemical engineering, and other scientific investigations on new uses of farm commodities and on the products thereof. The commodities being investigated in the Northern Utilization Research and Development Division are wheat, corn, and other cereal crops; soybeans and other oilseed crops (excepting cottonseed and peanuts); grasses, forages, and new crops; and agricultural residues.

An important part of the investigations is the search for uses of residues of agricultural products. An aspect of this work in dealing with sugarcane bagasse is covered in the present report.

CONTENTS

Page

INTRODUCTION 1

Background 3
Specific Objectives of the Investigation 6

LABORATORY AND PILOT-PLANT INVESTIGATIONS 8

Bagasse and Bagasse Fiber 8
  Sources and Varieties of Bagasse 8
  Physical Composition of Bagasse 9
  Chemical Composition of Bagasse 10
Pilot-Plant Separation of Pith from Fiber 13
Pulping Characteristics of Florida and Hawaiian Bagasse 14
  Whole Bagasse 15
  Separated Fiber 15
  Discussion of Results 17
    Whole Bagasse *vs.* Separated Fiber 17
    Florida Fiber *vs.* Hawaiian Fiber 17
    Liner Board Pulps from Separated Fiber 18
Discussion of Pulping Studies 18

SEMICOMMERCIAL-SCALE PRODUCTION OF CORRUGATING AND LINER PULPS FROM FLORIDA AND HAWAIIAN BAGASSE 19

Preparation of Separated Fiber from Florida Bagasse 22
  Fiber for Corrugating Pulp 22
  Fiber for Liner Pulp 22
Preparation of Corrugating Pulps from Whole Bagasse and Separated Fiber 25
Preparation of Liner Pulps from Separated Fiber 25
Discussion of Pulping Operations 27

SEMICOMMERCIAL-SCALE CONVERSION OF PULPS INTO CORRUGATING AND LINER BOARDS 29

Conversion of Experimental Pulps to Board 29
  Conversion to Corrugating Media on Fourdrinier Machine 29
  Conversion of Pulp to Corrugating Media on Cylinder Machine 31
  Conversion of Pulp to Liner Board on Fourdrinier Machine 32
Discussion of Board Machine Operations 32
  Florida Pulps 32
  Hawaiian Pulps 33

Page

Conversion of Commercial Pulps to Corrugating and Liner Boards.................... 35
Hardwood Semichemical Corrugating Medium.............. 35
Softwood Kraft Liner.............................. 35
Physical Properties of Corrugating and Liner Boards....... 37
Corrugating Media.................................. 37
Liner Boards....................................... 39

COMBINING OPERATIONS AND CONTAINER FABRICATION IN A COMMERCIAL BOXSHOP................................ 41

Combining and Fabrication............................ 41
Strength Characteristics of Combined Boards.............. 41
Discussion of Combining Operations...................... 45

EVALUATION OF SHIPPING CONTAINERS........................ 49

Tests by Forest Products Laboratory...................... 49
Tests by Container Laboratories, Inc. 50
Experimental Containers.............................. 50
Commercial Containers................................ 61
Commercial Evaluation in Rail and Truck Shipments......... 64
Tests by Pabst Brewing Company........................ 65
Tests by Libby, McNeill and Libby...................... 65

SUMMARY... 68

ACKNOWLEDGMENT.. 68

LITERATURE CITED.. 69

FIBER SHIPPING CONTAINERS FROM SUGARCANE BAGASSE

By

E. C. Lathrop,[1] S. I. Aronovsky,[2] S. B. Knapp,[3] F. W. O'Neil,[4] R. G. Hitchings,[5] A. J. Ernst,[6] and T. F. Clark[7]

INTRODUCTION

The manufacture of pulp and paper products, especially of packaging materials, is and will remain important in the improvement of living standards. How important pulp products are to the national economy and social development of the United States is indicated by the 31 million tons of pulp and paper produced and consumed in 1956. Demands of this magnitude require that much pulpwood and other natural fibers be withdrawn from the nation's resources each year.

Of the total pulp supplies used annually, about 7 million tons are for packaging material and containers. Predictions (1)[8] are that by 1965 demands for container and packaging materials will increase 40 percent, emphasizing the urgent need of conservatory measures for pulpwoods. More efficient utilization of woods presently pulped is one measure; another is utilization of fibrous crop residues which can be replenished annually.

Several foreign countries are already expanding their pulp and paper production, as well as improving their national economy through increasing use of crop residues. An important agricultural byproduct from which pulp products can be made in the United States and abroad is sugarcane bagasse.

---

[1] Retired. Peoria, Illinois. Formerly Head, Agricultural Residues Section.

[2] Deceased. Formerly In Charge, Pulp and Paper Unit, Agricultural Residues Section.

[3] Chemical Engineer. Hawaiian Sugar Planters' Association, Honolulu, Hawaii. Collaborator, 1952, with Northern Regional Research Laboratory.

[4] Head, Department of Pulp and Paper Technology, State University of New York, College of Forestry at Syracuse.

[5] Paper Technician, State University of New York, College of Forestry at Syracuse.

[6] Chemist, Pulping and Mechanical Processing Unit, Forage and Agricultural Residues Section.

[7] Chemical Engineer, In Charge, Pulping and Mechanical Processing Unit, Forage and Agricultural Residues Section.

[8] Numbers in parentheses refer to Literature Cited, at end of this report.

Sugarcane bagasse occupies a unique position among the fibrous agricultural residues because of its large-volume accumulation and availability within specific areas--the sites of the cane mills. This concentration accounts in part for the present commercial use of bagasse to produce insulation board and bleached papers in the United States proper--even though, tonnagewise, bagasse is a lesser crop residue. In certain insular and foreign locations bagasse is not only the major crop residue; it is the only major source of lignocellulosic fibers for pulping purposes. Furthermore, the attractiveness of bagasse for commercial pulping operations has been increased by recent development of practical methods for separating pith from fiber (7, 13).

Despite factors that have encouraged its use in pulp and paper manufacture, pith content has been a major hinderance to the economical production of quality pulps. The practical utility of bagasse as a source of fiber for commercial production of shipping containers was never adequately explored nor evaluated. Evidence acquired in laboratory studies at the Northern Regional Research Laboratory, the forerunner of the present Northern Utilization Research and Development Division, had indicated that bagasse pulps might be prepared having characteristics which would be useful in producing 9-point corrugating and 16-point liner boards. A broad research program on the use of bagasse to produce and evaluate experimental corrugating and liner boards and combined boards and shipping containers was proposed, initiated, and developed by this Regional Laboratory.

The influence of chemical and physical composition (pith content) of bagasse on processing conditions and product quality, and the influence of the various pulping procedures and refining treatments on the characteristics of the pulps, were investigated on laboratory and small pilot-plant scale at Peoria. Assistance in these studies and in subsequent investigations was provided through cooperation of the Hawaiian Sugar Planters' Association of Honolulu and San Francisco. Results of the initial phase served as the basis for selection of materials and conditions employed in subsequent semicommercial-scale tests. These operations, carried out under contract by the College of Forestry of the State University of New York at Syracuse, resulted in the production of bagasse corrugating and liner boards, which were combined, in a commercial boxshop, into container board and then fabricated into shipping containers. The relative quality of experimental and control containers was evaluated in laboratory tests and in commercial shipping tests.

This report describes the laboratory and pilot-plant scale studies conducted at the Northern Division, the semicommercial preparation of bagasse corrugating and liner boards at the College of Forestry, the conversion of corrugating and liners to container boards, fabrication of shipping containers, and evaluation of the experimental containers in laboratory and commercial tests.

Background

For more than a century, papermakers have been attempting the profitable manufacture of paper from bagasse. At first the manufacture of fine papers or newsprint was the goal, but difficulty in bleaching and low yields, along with other adverse economic factors, led to one failure after another. Successful manufacture of fine papers from bagasse was not achieved until World War II (6).

When the use of strawboard in the manufacture of fiber shipping containers began to expand during the early 1900's and wallboard began to have wider use, attention was directed to making them from bagasse. Strawboard and wallboard and similar products do not require bleached pulps, and pulping conditions require small amounts of chemicals and result in comparatively high yields.

Two developments succeeded commercially about 1920. The manufacture by the Eckart process of a mulch paper from bagasse, to be used for pineapple culture, was undertaken in a small plant in Hawaii and was continued for quite a number of years. More important, the Celotex Company[9] began the production of insulating building-board products--an entirely new industry--using bagasse as the raw material (10). This operation represented the first large-scale profitable utilization of bagasse.

Some years later, the Celotex Company purchased a board mill at New Iberia, La. Experiments were carried on at this mill to produce pulps from bagasse for paper or board manufacture. Whole bagasse was pulped with lime, or lime and caustic soda. These pulps were used for some years by blending with pulped waste paper, kraft pulps, and other furnish to make wrapping and board products.

About 1939 W. R. Grace and Company installed a small mill in Peru to make pulp from bagasse by cooking with caustic soda. This pulp, mixed with waste paper or kraft pulp, was made into wrapping and board products. After World War II this plant was enlarged, the processes for pulping improved, and a bleach plant added. Now the company makes a wide variety of paper and board products, generally from various mixtures of bagasse and wood pulp. A small mill is operated in Cali, Colombia, and another in Villa Ocampo, Sante Fe, Argentina, where low-grade boards are made from bagasse pulp and waste paper.

Because of the shortage of wheat straw in 1943, one of the strawboard companies requested the Northern Division to investigate the possibility of using bagasse as a raw material to make 9-point corrugating medium. Stored Louisiana bagasse was pulped with lime and caustic soda, according to conditions then used in the strawboard industry, with the result that satisfactory pulps were obtained in yields of about 75 percent (5). Following these laboratory tests, the strawboard mill made a commercial run, pulping the bagasse under standard mill conditions and making the pulp into 9-point corrugating medium. This whole operation was reported to be satisfactory. After the war one of the larger strawboard mills used bagasse for several months to produce a pulp which was blended with straw pulp to make corrugating medium (11). This practice was discontinued because of the high delivered cost of the baled bagasse in a wheat-producing area.

---

[9] This and all subsequent references to commercial firms or to equipment by specific names are made for clarity and conciseness of presentation and are not to be construed as endorsements or recommendations by the United States Department of Agriculture.

One of the most important attributes of a corrugating medium is crush resistance. It was this natural property of strawboard that led to the invention of corrugating medium and started the manufacture of fiber shipping containers. The use of strawboard in this industry increased rapidly and until 1926 it was the only material used for this purpose.

The yields of pulp from straw were high and straw costs were low--so strawboard could be made at low cost. In order for hardwood pulps to compete in the manufacture of corrugating medium, it was necessary to use low-cost hardwoods and obtain high yields of pulps.

In the thirties the Forest Products Laboratory (U. S. Forest Service) at Madison, Wis., and some paper companies independently began to study the pulping of hardwoods by new methods which gave rather high yields of pulp. The Mead Corporation had available large amounts of spent chestnut chips from the manufacture of tannin and sought to make a corrugating board pulp from them. After considerable experimental work, the railroads accepted the wood pulp corrugating medium in fibrous shipping containers. The Forest Products Laboratory used neutral sodium sulfite as a chemical for pulping hardwoods, producing a raw type of pulp in high yields.

It has long been known that pulps made from straw require less treatment in the beater than wood pulps to produce products of comparable characteristics. Indeed, it is somewhat difficult not to overtreat straw pulps in the beater. Overtreatment produces papers that are often too parchmentlike, horny, or "tinny." This characteristic was believed to be due in part to the high pentosan content of the straw pulps. Hardwoods contain larger percentages of pentosans than softwoods. The semichemical process applied to hardwoods resulted in high yields of pulps of high pentosan content. However, continued and intensive research on semichemical pulping of hardwoods was necessary before this media could displace competitive strawboard. By improving the pulping conditions so as to increase pulp yields, the pentosan content of the pulps increased and quality was improved. By World War II the quality of semichemical corrugating medium was equal or superior to that made from straw. As a result most new mills built for the production of corrugating medium since then use the Forest Products Laboratory's semichemical process.

In 1947-48, the strawboard industry requested the Northern Division to undertake cooperative research to improve the quality of straw corrugating medium, particularly crush resistance. It was found that lime, used wholly or in part as a pulping chemical in all of the mills, was responsible for making a product of lower crush resistance. The Northern Division developed several new pulping formulations which produced pulps of higher quality. The various mills of the industry are now using one or the other of these new methods.

Not long after this work was reported, a radically new process for pulping straws and stalks was developed at the Northern Division (2, 3). This process, which pulps at atmospheric pressure and near 100° C., is known as the Mechano-Chemical Process because the pulping action is brought about by a combination of mechanical and chemical treatment. The process is carried out in simple vessels, for example, Hydrapulpers, already in wide use in the paper industry for pulping waste papers. As compared with pressure pulping, the Mechano-Chemical Process uses the same amount of chemical on the basis of dry material, either caustic soda or kraft chemicals, but the duration of pulping is much shorter, the yield of screened pulp is higher, and the pulp is comparable in strength to those produced by conventional processes using pressure. The good strength properties of the pulps made by this process are due to the mild pulping conditions which produce a pulp higher in pentosan content than pressure-cooked pulps.

This process was first developed for making pulp from straw for corrugating medium. Later the process was applied successfully for making fine paper pulps from straws and stalks. In 1949 a commercial trial of the Mechano-Chemical Process for making corrugating medium was successfully carried out at the Noblesville, Ind., mill of Ball Brothers Company (9). In recent years the process has been in successful commercial operation at the Huize "UNION" mill, Oude-Pekela, Netherlands. At this mill oat straw is pulped in a 10-foot Hydrapulper for 1 hour at 98° C. using 5.5 percent caustic soda on a basis of air-dry straw. This operation is very successful.

The commercial utility of the Mechano-Chemical Process having been demonstrated for making corrugating medium from wheat straw, it was logical to consider its use in pulping bagasse. An extensive program on pulping bagasse had been initiated and was under way at the Northern Division when a southern board mill became interested in bagasse as a raw material for making boards for shipping containers. After several visits to the Northern Division, when Louisiana bagasse was pulped by the Mechano-Chemical Process, this company undertook developmental work at its mill. Whole Louisiana bagasse was pulped in a 3-foot Hydrapulper and the pulp converted to corrugating in a series of machine runs at the Forest Products Laboratory. The Northern Division cooperated in this work, supplying wheat straw pulp made by the Mechano-Chemical Process. The southern mill supplied their standard bogus corrugating pulp and procured commercial semichemical hardwood pulp. Similar paper machine runs were made using each of these pulps. The boards made were tested and were corrugated at the Forest Products Laboratory. This study demonstrated that the medium made from straw or bagasse pulp was superior in strength, particularly crush resistance, to either the semichemical wood or bogus medium. There was little difference between the physical properties of the bagasse and straw products. Owing to problems of water supply and waste disposal, the southern board company has not yet undertaken the use of bagasse.

In 1951 the Hawaiian Sugar Planters' Association, having become interested in the commercial utilization of bagasse, entered into a cooperative agreement with the Northern Division to assist in an experimental program on bagasse utilization. Particular attention was directed to the development of a practical method for separating whole bagasse into fiber and pith, of a method for determining the absorption capacity of pith, and of a standard method for evaluating various types of bagasse in respect to their pulping characteristics; also a study was made applying to bagasse the Mechano-Chemical Process for producing board pulps. Progress in the solution of these problems made possible the complete development reported herein.

Specific Objectives of the Investigation

The manufacture of fiber shipping containers comprises a series of intricate operations: Pulping; converting pulps into corrugating and liner boards; combining corrugating medium and liner board by use of hot corrugating rolls and pasting machinery into a sandwich of a corrugated board having a liner board glued to each face; and finally fabricating the combined board into shipping containers of definite size and shape. Decisions to select specific raw materials for production of container boards must be based on continuity of supply, economics of procurement and conversion, satisfaction of service requirements, and the quality of the finished shipping containers. Such information is expensive to obtain. Because of favorable results obtained in a laboratory investigation on the pulping of sugarcane bagasse a broad development program was planned. This program was designed to obtain answers to a number of technical questions, and in turn provide information necessary for the preparation of cost estimates.

The program consisted of several phases which are outlined below:

1. Laboratory and pilot-plant scale investigations at the Northern Utilization Research and Development Division.

   1. Analyses of bagasse samples and selection of two types of bagasse having significant differences in character and location of production.
   2. Development of a practical method of separating whole bagasse into fiber and pith.
   3. Determination of the relative merits of conventional pressure processes and the Mechano-Chemical Process for pulping bagasse for corrugating media.
   4. Determination of the optimum conditions for producing corrugating pulps from whole bagasse and separated fiber and liner pulps from separated fiber on a pilot-plant scale.

II. Semicommercial-scale production of corrugating and liner pulps from Florida and Hawaiian bagasse.

   1. Preparation of separated fiber from Florida bagasse with an 8-foot Hydrapulper and Jonsson screen.
   2. Preparation of pulps from whole bagasse and separated fiber by the Mechano-Chemical Process for corrugating media and liner boards.

III. Semicommercial-scale conversion of pulps into corrugating media and liner boards.

   1. Conversion of Florida and Hawaiian pulps into corrugating media on a 40-inch trim paper machine with a Fourdrinier wet end.
   2. Conversion of Florida whole bagasse pulp to corrugating medium on a 40-inch trim paper machine with a cylinder wet end.
   3. Conversion of blends of bagasse pulps and virgin kraft pulps into liner boards.
   4. Production of control corrugating medium and liner board from commercial pulps.
   5. Evaluation of physical properties of experimental, control, and commercial corrugating and liner boards.

IV. Combining operations and container fabrication under commercial conditions.

   1. Combining corrugating media and liner boards.

2. Evaluation of combined boards.

3. Container fabrication.

V. Laboratory evaluation of shipping containers.

1. Tests by the U. S. Forest Products Laboratory.

2. Tests by Container Laboratories, Inc.

VI. Commercial evaluation of shipping containers in rail and truck shipments with commercial containers.

LABORATORY AND PILOT-PLANT INVESTIGATIONS

Bagasse and Bagasse Fiber

Sources and Varieties of Bagasse

Bagasse from two commonly grown varieties of sugarcane, one from Florida and the other from Hawaii, were selected for these investigations.

The Florida bagasse was produced by the United States Sugar Corporation, Clewiston, Fla., in the spring of 1952 by grinding cane variety F. 31-436. This variety is one of the most important grown in the Everglades. It is a fairly large barreled cane and has a rather high pith content. The Everglades' soils for cane culture are either black muck or brown peat and the bagasse is a dirty grey in color.

Two different lots of this bagasse were secured. One represented whole bagasse without any removal of pith or dirt, the other material sold by the company for mulch or litter.

The whole bagasse, coming directly from the cane mill, was dried in a rotary dryer and baled. The litter type was prepared by passing the bagasse from the cane mill over a shaker screen to remove some pith and dirt before drying. The dried bagasse was again screened to remove as much dirt, pith, and fine fiber as practical and was baled. About 70 percent of the dry weight of the original whole bagasse was recovered in these screening operations. The discarded screenings consisted of about 12 percent fine fibers, 15 percent pith, and 3 percent water solubles based on dry whole bagasse. These preparatory treatments were carried out by the United States Sugar Corporation.

The Hawaiian bagasse was from cane variety 8560 ground at the Oahu sugar mill in the spring of 1952. Owing to the method of mechanically harvesting cane in Hawaii, the bagasse contained enough silt to color it a yellowish-orange. The bagasse was collected and prepared by the Experiment Station of the Hawaiian Sugar Planters' Association. Whole bagasse was air-dried and packed into bags. Separated fiber was also prepared in Hawaii from this variety of bagasse by a wet-separation process developed at Peoria (13). This process consisted in treatment of the bagasse at about 7 to 8 percent consistency in water in an 8-foot Hydrapulper until the pith was loosened from the fiber. The contents of the Hydrapulper were diluted to about 0.5-percent consistency and screened in a rotary screen. The fiber was drained, air-dried, and packed into bags.

These lots of bagasse, comprising about 20 tons in all, were provided by the United States Sugar Corporation and the Hawaiian Sugar Planters' Association. Most of the lots were shipped to Syracuse, N. Y., for the large-scale tests and a smaller amount sent to Peoria for the preliminary work.

Physical Composition of Bagasse

Determination of the relative proportions of fiber, pith, dirt, and solubles in bagasse is, at best, an approximation. After investigating a number of methods, the following procedure was adopted as providing the most reliable data:

An entire bale of Florida bagasse or bag of Hawaiian bagasse was broken up by hand, mixed, and quartered to obtain a sample of approximately 20 lb. (oven-dry basis). The sample was placed in an autoclave with 3 times its weight of water and treated with direct steam at 5 p.s.i. for 20 min. Air and noncondensable gases were vented from the autoclave several times during the steaming. The purpose of this treatment was to make the fibers soft and flexible and to remove air from the pith particles.

The steamed mass, together with any free water, was removed from the autoclave and passed through a 24-inch double-disc refiner fitted with "devil-tooth" plates, the setting between the plates being 0.3 inch. This treatment effectively rubbed loose the pith from the fiber bundles of the bagasse. All of the liquid draining from the fiber was collected, mixed, and aliquot samples were evaporated to dryness and ashed to determine total and volatile soluble solids and ash. The treated fibrous material was dried at a temperature of 103° C. Any lumps in the dried mass were broken up by hand and the material was screened successively over 3 vibrating sifters dressed with perforated sheet metal having 0.436-inch-, 0.156-inch-, and 0.095-inch-diameter holes. The material retained on the screens was collected as fiber. By careful inspection this fiber was estimated to contain about 5 percent of pith.

The material passing the 0.095-inch screen consisted of pith with some small fiber. To determine the amount of fiber present in the pith, samples of the pith fraction were treated in the following manner: Three-gram portions were placed in a Waring Blendor containing 500 ml. of water to which a wetting agent had been added. At the end of 3 minutes the suspension was transferred to a Bauer-McNett classifier. All material retained by a 14-mesh screen was considered fiber; the remainder, containing a small number of fine fibers, was considered pith. The action of the Blendor broke down large pith cells but did little cutting of the small fibers. Based on these procedures the final estimates of composition were made. These are presented in Table 1.

Chemical Composition of Bagasse

The proximate chemical composition of whole bagasse, fiber, and pith was determined for both Florida and Hawaiian materials. Whole bagasse represents the material as received without any prior screening or cleaning treatment. "Commercial grade" fiber and pith were prepared from whole bagasse. Separation of the pith from the fiber was carried out in the following manner: Approximately 50 lb. whole bagasse was placed in a 3-foot Hydrapulper with water to make about 6.5 percent consistency. Operation of the Hydrapulper for 25 minutes was sufficient to loosen the pith from the fiber. The contents of the Hydrapulper were then washed into a drain box with a perforated bottom having 0.04-inch-diameter openings. The drained mass was diluted in a 500-gal. tank to 0.5 percent consistency, was mixed thoroughly by a high-speed agitator, and the slurry was pumped to a pilot-plant size Jonsson screen having a screen plate perforated with

Table 1.--Physical composition of Florida and Hawaiian bagasse, moisture-free basis

	Florida F. 31-436		Hawaiian 8560, whole
	Whole[1]	Litter grade	
	Percent	Percent	Percent
Fiber	69.6	73.4	60.5
Pith	30.4	14.4	32.8
Soluble volatile solids	(2)	6.5	1.6
Soluble nonvolatile solids, dirt, and losses	(2)	5.7	5.0

[1] Reported by Dr. B. A. Bourne, United States Sugar Corporation, Clewiston, Fla.

[2] Not determined.

0.117-inch round holes. Most of the fiber passed over the screen. The pith with some fine fiber passed through the screen and was collected in a 500-gal. tank. This suspension was again pumped over the Jonsson screen. Most of the remaining fiber was removed. The pith passing through the Jonsson screen was collected over a Link-Belt vibrating screen dressed with 100-mesh wire. This pith was dried at about 95° C., blended, and sampled for analysis. Fiber samples from each passage over the Jonsson screen were practically free from pith. These samples were combined, dried at 95° C., mixed well, and sampled for analyses.

None of the fractions obtained by the described procedure consist of pure fiber or pure pith; rather, they are representative of high-grade "commercial" material. For the most part, the dirt and carbon specks have been washed from the fiber and the fiber samples have a bright appearance. Also, a large part of the dirt has been washed from the pith, and a small part of the original pith which had been granulated during the separation treatment was lost.

The samples used for analysis were ground in a Wiley mill to pass a screen having 1-mm. round holes. Ash, pentosans, extractives, Cross and Bevan cellulose, and alpha-cellulose were determined according to TAPPI methods (15). Analyses for lignin and MEA cellulose were made by methods previously described (4, 14). Results of these analyses are presented in Table 2.

These data show that while the Florida whole bagasse outwardly appeared to contain more dirt than the Hawaiian, actually the Hawaiian had a higher ash content. This might be explained in part on the basis of contamination resulting from the soils on which the sugarcanes were grown. The peat and muck soils of Florida contain large amounts of organic matter not contributing to the ash content, whereas the silt of Hawaii is of volcanic origin and its presence is reflected in the ash value of the bagasse to which it adheres.

Note that the lignin contents of all of the Hawaiian samples are higher than those of the Florida samples. Cane is harvested in Hawaii after a growing season of about 22 months and is fully mature; while the Florida cane as harvested at 9-10 months is less mature. In general, as plants become more mature, their lignin content increases.

The pentosan and Cross and Bevan cellulose contents of the whole bagasse involved in this study are quite similar. Data presented elsewhere (12), however, indicate that the values for these constituents are generally somewhat higher in the Hawaiian varieties than in the Florida bagasse. These data, as well as the present data, show that the Florida whole bagasse contains more extractives than the bagasse from Hawaii or elsewhere. While characteristics of soils in the two regions might explain in part these differences in composition, it is believed that maturity of canes at time of

Table 2.--Chemical composition of Florida and Hawaiian bagasse, separated fiber and pith, moisture-free basis

NU No.	Material	Ash	Lignin	Pentosans[1]	Extractives in--			Cross and Bevan cellulose					
								C and B cellulose		Alpha cellulose			
										As run		Basis original	
					Hot water	Alcohol benzene	1% NaOH	Ash-free	Pentosans in	Ash	Pentosans in	Ash- and pentosan-free	
		%	%	%	%	%	%	%	%	%	%	%	
9941	Florida variety F.31-436 Clewiston - 1952												
	Whole bagasse	1.6	16.8	27.9	15.5	6.4	43.2	48.8	32.7	66.5	5.3	30.8	
	Separated fiber	1.0	18.6	32.5	3.2	3.7	32.1	58.1	29.3	68.4	3.9	38.2	
	Pith	4.3	18.9	32.7	4.7	3.3	36.6	50.2	30.1	66.0	4.9	31.0	
9992	Hawaiian variety 8560 Oahu - 1952												
	Whole bagasse	5.4	21.3	27.7	5.7	3.2	33.9	50.2	27.4	69.6	8.8	31.8	
	Separated fiber	2.0	21.1	30.7	2.4	3.6	28.8	56.0	28.8	73.4	10.4	38.3	
	Pith	3.3	20.0	33.0	1.5	2.1	30.8	53.5	29.7	62.7	6.7	31.5	
10122	Hawaiian bagasse Fiber shipped to Syracuse, N. Y.	1.1	21.6	30.7	2.7	2.7	30.9	57.9	30.0	73.9	12.4	37.5	

---

[1] Pentosans = furfural x factor 0.8.

harvest has greater influence on composition. Pentosan and Cross and Bevan cellulose values are higher, but alpha-cellulose values are lower for Florida fiber than for Hawaiian fiber. Composition of fiber separated in Hawaii with an 8-foot Hydrapulper and of fiber separated in Peoria under laboratory conditions is very similar, indicating that the fibers are of comparable quality. This shows that the depithing operation in Hawaii produced a very acceptable fiber for pulping. Comparing the data obtained on pith samples with those from fiber, it will be noted that the pith samples contain more ash, more lignin, more pentosans, more extractives but less Cross and Bevan cellulose and less alpha-cellulose. The higher ash and extractive content of the pith is due to its greater specific surface area and hence its greater absorptive capacity. This propensity of pith to accumulate dirt and other impurities makes it difficult to prepare bleached pulps from bagasse containing large amounts of pith.

Pilot-Plant Separation of Pith from Fiber

In developing pith-fiber separation techniques it is most desirable to avoid any processing step which will cut or shorten the bagasse fiber. The presence of short fiber makes any method of separating the pith from the fiber by either wet or dry screening more difficult. Furthermore, contamination of the pith fraction with short fibers not only lowers the absorptive power of the pith but results in a loss of pulp-making fibers. Pith particles are deeply embedded in the rind fibers of the bagasse and surround the fibro-vascular bundles contained in the interior of the cane stalk. If moist bagasse is rubbed vigorously between the hands, the internal friction developed in the mass loosens the pith very well without damage to the fiber. The several separation techniques studied simulated this rubbing action. The following is a description of the procedure adopted:

Bagasse was treated in a 3-foot laboratory Hydrapulper at as high a consistency as possible. Depending on the character of the bagasse, the maximum consistency which could be obtained in the treatment was found to vary between 6 and 7 percent, and the time required for the treatment varied between 15 and 25 minutes. When dry bagasse was processed, it required a few minutes for it to be thoroughly wetted. A 1-percent suspension in water of the Hydrapulper-treated bagasse could be separated into clean coarse fiber and a mixture of pith and fine fiber by pumping it onto a Jonsson screen fitted with a screen plate having round holes of 0.25-inch diameter. The pith mixture passed through the screen at about 0.3-percent consistency. The fine fiber could be separated from the pith by pumping the pith suspension over the Jonsson screen fitted with a plate having 0.09-inch-diameter round holes. The fine fiber obtained was added to the coarse fiber from the first screen and the mixture was satisfactory for pulping. A careful examination of this fiber showed that it generally contained less than 5 percent pith in the form of small clumps clinging to fibers. The yield of fiber from the various samples of bagasse varied between 60 and 65 percent of the original bagasse. The fiber from the Jonsson screen had a consistency of about 12 percent but drained in a short time to about 17 percent. This pilot-plant study was carried out at the Northern Division with the cooperation of Messrs. H. I. Mahon and R. L. Brown, collaborators of the Hawaiian Sugar Planters' Association.

The above method was used in making fiber separations both in Hawaii and at Syracuse, N. Y. Pilot plants installed at both these locations had 8-foot Hydrapulpers. In Hawaii, instead of using a Jonsson screen, a locally made rotary screen was used. At Syracuse the fiber was passed once over a Jonsson screen and the pith was collected over a decker dressed with a 40-mesh wire and discarded. In Hawaii the pith was collected, dried, and used as an absorbent for blackstrap molasses in feeding experiments.

An analysis of the depithed fiber prepared at Syracuse from Florida bagasse indicated that it contained 7 percent pith. The separated fiber prepared in Hawaii contained 6 percent pith.

Pulping Characteristics of Florida and Hawaiian Bagasse

An extensive series of pulping tests were carried on at the Northern Division to determine the best methods and conditions for producing pulps for corrugating and liner-board manufacture. In these tests the varieties of bagasse from Florida and Hawaii selected for shipment to Syracuse were used. Pulping tests were made on samples of whole bagasse and of separated fiber. The separated fiber was prepared at the Northern Division in the 3-foot Hydrapulper as described previously.

Caustic soda as the pulping chemical was used in various amounts to determine the preferred concentration for effective pulping of bagasse. Pressure cooking has been a standard practice in the container board industry. For pressure cooking at the Northern Division a 5-hour period at 140° C., a condition satisfactory for pulping wheat straw, was adopted as a standard procedure for pulping bagasse. Charges of 8 lb. of bagasse or fiber were placed in tumbling 10-gal. stainless-steel digesters with a liquid-solids ratio of 7:1. The digesters were brought to temperature as rapidly as possible using indirect steam in the jacket, and at the end of pulping period the pressure was released, the contents of the digester dropped into a screen box provided with a screen plate having 0.09-inch holes, and drained. The pulp was defibered in a Noble and Wood beater and washed. The washed pulp was collected, partially dewatered, weighed, and sampled for moisture to determine yield. The pulp was then evaluated in accordance with TAPPI methods.

Cooks by the Mechano-Chemical Process were made in the 3-foot stainless-steel Hydrapulper. Consistency at the start of cooking was 10 percent and, depending on yield, varied from about 6 to 7.5-percent consistency at the end of the cook. The necessary water and chemical were added to the Hydrapulper and, by the injection of direct steam, the solution was brought to boiling. The impeller of the pulper was started and 50 lb. of bagasse added as rapidly as a vortex could be maintained in the pulper. It took a minute or two for all the bagasse to be wetted. The temperature in the Hydrapulper was maintained between 98°-100° C. for 1 hour, after which the contents of the pulper were dumped into a screen box, the Hydrapulper washed down with water, and the pulp allowed to drain. The drained pulp was then passed through a 24-inch Bauer refiner using waveline plates for defibering followed by the operations of dewatering, screening, washing, and testing as for pressure-cooked pulps. Typical results obtained in pulping whole bagasse and separated fiber by the pressure and Mechano-Chemical Processes are presented in Table 3.

Whole Bagasse

Based on a careful appraisal of the data obtained in the pulping tests with whole bagasse, the use of whole bagasse as the raw material is not encouraging. However, the Mechano-Chemical Process produced pulp in higher yield and of lower freeness, crush resistance, bursting and tensile strengths, and of higher tearing resistance than did the pressure process (cook 1187 vs. 1228). Corrugating boards of acceptable quality could be prepared from these pulps but they would be very slow-running on a paper machine. No significant differences in pulp properties resulted when Florida and Hawaiian whole bagasse were pulped with 8 percent of caustic soda by the Mechano-Chemical Process (cook 1228 and 1243). The pulps from both materials were of low freeness, but by slow machine operation or by the use of large amounts of waste corrugating pulps as blends, the pulps should produce medium grade corrugating board. Hawaiian whole bagasse cooked by the Mechano-Chemical Process using 10 percent of caustic (cook 1245) produced a pulp of about the same freeness as obtained in cooks 1187 and 1228 but of somewhat lower yield and of somewhat better strength properties. Because of the low freeness of either the pressure or Mechano-Chemical Process cooked pulps from whole bagasse, they are not considered satisfactory for manufacture of high-grade corrugating board on fast-running board machines. The pressure cooks evidently destroyed more pith than cooks by the Mechano-Chemical Process, and for this reason the pressure-cooked pulps are slightly freer.

Separated Fiber

Comparisons of results of pressure and Mechano-Chemical pulping procedures as applied to separated bagasse fiber show that: With Florida fiber and 8 percent of chemical (cook 1255 vs. 1229) the

Table 3.--Data on the pulping of Florida and Hawaiian bagasse by pressure and Mechano-Chemical cooking methods

Cook No.	Material	Cooking conditions				Pulp yields[1]			Chemical analysis[2]			Initial freeness S.-R.	Strength characteristics 500 ml. S.-R.[3]				
		Chemical[1]	Time	Temperature	pH final liquor	Crude	Screen-washed	Fines	Ash	Lignin	Pentosans		Bursting strength	Tensile strength	Tearing resistance	Riehle ring crush	Flat crush
		% NaOH	hrs.	°C.		%	%	%	%	%	%	ml.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb. x 100	lb.	lb./sq. in.
								Florida Bagasse, Variety No. F.31-436, Year 1952									
1187	Whole	8.0	5	140	-	60.7	58.9	1.8	-	-	-	685	83	166	62	42	-
1228	Whole	8.0	1	98-99	-	70.4	67.7	2.5	-	-	-	480	58[4]	112[4]	110[4]	34[4]	58[4]
1255	Separated fiber	8.0	5	140	-	71.3	69.4	1.9	-		-	770	89	144	66	45	-
1229	Separated fiber	8.0	1	98-99	10.7	73.2	70.7	2.5	1.0	10.3	35	680	96	173	66	45	76
1230	Separated fiber	10.0	1	98-99	11.5	72.0	71.0	1.0	1.7	8.2	33	650	95	182	75	45	75
1231	Separated fiber	12.0	1	98-99	11.9	68.9	63.8	1.3	1.0	6.6	36	720	113	190	58	-	540[5]
1244	Separated fiber	13.0	1	98-99	11.9	70.2	65.2	3.5	1.3	5.4	33	720	111	187	56	-	900[5]
1232	Separated fiber	14.0	1	98-99	11.8	69.6	66.0	2.6	1.2	5.9	34	680	117	198	56	-	700[5]
								Hawaiian Bagasse, Variety No. 8560, Year 1952									
1243	Whole	8.0	1	98-99	11.1	72.1	68.4	3.7	-	-	-	510	67[4]	129[4]	72[4]	35[4]	63[4]
1236	Separated fiber	8.0	1	98-99	11.0	76.1	74.2	1.9	-	-	-	700	79	130	92	35	72
1245	Whole	10.0	1	98-99	-	68.5	65.6	2.9	-	-	-	510	76[4]	131[4]	76[4]	36[4]	64[4]
1239	Separated fiber	10.0	1	98-99	11.5	74.8	71.9	2.9	1.8	10.0	33	730	83	146	86	37	66
1256	Separated fiber	10.0	5	140	-	68.5	67.3	1.2	1.3	8.2	32	855	90	142	112	40	-
1240	Separated fiber	12.0	1	98-99	11.8	73.0	69.9	3.1	1.4	9.4	34	740	89	151	88	40	70
1241	Separated fiber	14.0	1	98-99	12.2	72.1	58.3	7.4	1.6	9.1	32	820	81	150	70	-	250[5]
1242	Separated fiber	16.0	1	98-99	12.2	71.1	62.4	4.8	1.6	8.8	31	800	82	155	72	-	280[5]
1251	Separated fiber	18.0	1	98-99	12.3	69.4	65.4	4.9	1.6	9.2	32	795	81	158	72	-	320[5]

---

[1] Basis oven-dry raw material.

[2] Basis oven-dry screened pulp.

[3] NU-Strength Data: From handsheets

Basis weight = Pounds in ream 25 x 40-500.

$$\text{Bursting strength} = \frac{\text{Mullen, p.s.i.}}{\text{Basis weight}} \times 100.$$

$$\text{Tensile strength} = \frac{\text{Grams to break 15 mm. strip.}}{\text{Basis weight}}$$

$$\text{Tearing resistance} = \frac{\text{Force in grams to tear single sheet}}{\text{Basis weight}} \times 100$$

Riehle ring crush: 2-inch specimens.

[4] At freeness of 400 ml. S.-R.

[5] Schopper fold number.

Mechano-Chemical pulp was produced in slightly higher yield. This pulp had higher bursting and tensile strengths and was equal to the pressure-cooked pulp in tear and crush resistance. A like comparison of these methods in cooking Hawaiian fiber with 10 percent of chemical (cook 1256 vs. 1239) showed that the Mechano-Chemical Process produced pulp of about 6-percent higher yield at a somewhat lower freeness and higher tensile strength but at slightly lower burst strength and resistance to tear and crush. The crush resistance is ample for making high-grade board.

Discussion of Results

Whole Bagasse vs. Separated Fiber:

A comparison of the pulps prepared by the pressure cooking of whole bagasse vs. separated fiber showed that: With Florida samples using 8 percent of caustic (cook 1187 vs. 1255), pulp from the fiber was produced at 10-percent higher yield, the pulp had a higher freeness, was superior in burst and tear strengths and in crush resistance, and was slightly lower in tensile strength. Comparing the Hawaiian samples using 8 percent of chemical pulped by the Mechano-Chemical Process (cook 1243 vs. 1236), the yield of pulp from fiber was 6 percent higher; the freeness, burst strength, and resistance to tear of its pulp were higher; and the other properties were essentially the same as pulp made from whole bagasse. When 10 percent of chemical was used in Mechano-Chemical cook 1245 vs. 1239, the yield of pulp from fiber was 5 percent higher, and all of the physical properties of the pulp, with the exception of crush resistance, were better than pulp from the whole bagasse.

Florida Fiber vs. Hawaiian Fiber:

A comparison of the results of pulping tests with the Mechano-Chemical Process showed that: When using 8 percent of chemical (NaOH) the yield of pulp from the Hawaiian fiber (cook 1236) was 3.5 percent more than from Florida (cook 1229) and the freeness values of the Hawaiian pulp and Florida pulp were about the same, but all physical properties, tearing resistance excepted, of the Hawaiian pulp were lower than those of the Florida pulp. When the pulp prepared by cooking Florida fiber with 8 percent of chemical (cook 1229) is compared with Hawaiian fiber cooked with 10 percent of chemical (cook 1239), it will be noted again that the Florida pulp has better physical tests. A comparison of Florida fiber pulped with 8 percent and with 10 percent of chemical (cook 1229 vs. 1230) shows that the two pulps are produced at essentially the same yield and have equal physical properties. Comparing pulps produced from Hawaiian fiber by the use of 10 percent of chemical vs. 12 percent, it will be noted that the higher amount of chemical produces a pulp of slightly better bursting and tensile strength and crush resistance, but of slightly lower yield, with lower, but satisfactory, freeness.

Liner-Board Pulps from Separated Fiber:

Liner-board pulps have different physical requirements than corrugating pulps. While crush resistance is one of the most important properties of corrugating media, the ability of liner boards to withstand creasing during box fabrication is as important as the burst and tensile strength properties. Pulps prepared for use in liner productions should, therefore, contribute to the crease properties of the liners. It is evident that more lignin must be removed in the preparation of such pulps, and to do so larger amounts of cooking chemical will be required. Reference to the data in Table 3 shows that a pulp of maximum strength and yield was obtained from Florida fiber with about 13 to 14 percent caustic (cooks 1244 and 1232). On the other hand, pulping Hawaiian fiber with up to 18 percent of caustic soda did not result in a pulp with strength characteristics, tear excepted, equal to those of Florida pulps. The lignin content of the Hawaiian pulps persisted at a higher level than did that of the Florida pulps.

Discussion of Pulping Studies

These tests lead to the conclusion that pulps made from whole bagasse, by either pressure or Mechano-Chemical pulping processes, will have low freeness which will permit only low-speed conversion on the paper machine or will require the addition of rather large amounts of free waste-paper pulps for faster machine operation.

The pulps made from separated fiber by either the Mechano-Chemical or pressure pulping methods are much freer and of more acceptable strength properties than those from whole bagasse. Such pulps will permit faster running on the board machine and will not require large additions of waste-paper pulps.

The higher yields and the simpler and less time-consuming operations of the Mechano-Chemical Process favor its use over the pressure procedures.

The variety of Hawaiian bagasse studied is more difficult to pulp than the Florida variety. This is believed to be due to the fact that the Hawaiian bagasse fiber is from a more mature plant and is more highly lignified.

For producing corrugating pulp it is indicated that the chemical requirements for Florida fiber are 8 to 10 percent of caustic and for the Hawaiian fiber 10 to 12 percent of caustic. For making liner-board pulps the Florida fiber requires 13 to 14 percent of caustic and the Hawaiian fiber 16 percent or perhaps more.

Based on these results it was decided that the Mechano-Chemical Process would be selected for use in the Syracuse pilot-plant experiments to manufacture corrugating and liner board from bagasse.

SEMICOMMERCIAL-SCALE PRODUCTION OF CORRUGATING AND LINER PULPS FROM FLORIDA AND HAWAIIAN BAGASSE

In order to arrive at a final conclusion as to the utility of bagasse for the manufacture of shipping containers, it was highly desirable to arrange for commercial- or semicommercial-scale pulping, conversion of pulps to boards, combining of corrugating and liner boards into container boards, fabrication of boards into boxes, and finally truck and rail shipping tests. A contract to implement the production studies was entered into with the College of Forestry of the State of New York through the Research Foundation of the State University of New York. The College of Forestry had the most complete facilities for carrying out such a program. It possessed a paper machine with 40-inch trim that could be operated with either a Fourdrinier or cylinder wet end. Beaters and refining engines were available. However, for studies with bagasse, certain modifications in equipment or procedure were required. For pulping, an 8-foot Hydrapulper was available together with necessary chests, a Jonsson screen, a decker, a flat screen, and a disc refiner. This Hydrapulper had been designed for repulping waste-paper stock rather than for depithing or pulping bagasse by the Mechano-Chemical Process; consequently the impeller pattern and the connected power were not optima. The Jonsson screen proved quite satisfactory for separating pith from fiber but the flat screen had too small a capacity which made screening of the stock difficult. More important, the pipe lines were all 4 inches in diameter and contained many right-angle couplings. This caused a great deal of difficulty in the depithing operation since the lines and pumps continually plugged because of the very free and coarse bagasse fiber. The washing equipment, although designed for handling wood pulps, was more suitable than the washer-beater for treating bagasse pulps. The decker was dressed with a 40 x 60-mesh wire which was rather coarse for bagasse pulps and permitted fiber losses greater than would be expected had the equipment been designed for this specific job. Improvements in characteristics or in design of the equipment would likely lead to greater efficiency and improved properties in the final pulps. In the absence of a pulp screen on the paper machine a standard flat screen was used to remove lumps, sand, and stone from the beaten pulps. Machine speeds ranged from 56 to 110 f.p.m. during these studies. Higher machine speeds might have been used had the capacity of the dryer section been greater. Increased loading of the calender stack would have been desirable for optimal finish on the corrugating and liners produced.

Although the results of the Northern Division on pulping whole bagasse indicated that the pulps would necessitate slow paper machine operation, it was decided, for comparative purposes, to include both Florida and Hawaiian whole bagasse in the program of experimental runs for corrugating board production. The Hawaiian Sugar Planters' Association arranged to prepare separated fiber at their pilot plant. The wet fiber after pith separation was air-dried before bagging and

Table 4.--Code used to designate various types of board made at Syracuse, New York

These code designations indicate the types of materials used in the various corrugating and liner boards produced in 40-inch trim during semicommercial-scale operations at the College of Forestry, Syracuse, N. Y. Unless noted otherwise boards were produced on a Fourdrinier machine. Other exceptions are noted.

FFC	Florida Fiber Corrugating. -- A 9-point corrugating medium produced from a blend of Florida fiber, 85 percent, and waste kraft corrugating, 15 percent.
FWC	Florida Whole Corrugating. -- A 9-point corrugating medium produced from a blend of Florida whole bagasse pulp, 85 percent, and waste kraft corrugating, 15 percent.
FWCC	Florida Whole Corrugating Cylinder. -- A 9-point corrugating medium produced on a cylinder machine from a blend of Florida whole bagasse pulp, 85 percent, and waste kraft corrugating, 15 percent.
FFL	Florida Fiber Liner. -- A test liner board produced from a blend of Florida fiber pulp, 50 percent, and virgin kraft pulp, 50 percent
FFLY	Florida Fiber Liner. -- A test liner board produced from a blend of Florida fiber pulp, 25 percent, and virgin kraft pulp, 75 percent.
FFLX	Florida Fiber Liner. -- A test liner board produced from Florida fiber pulp, 100 percent.
HFC	Hawaiian Fiber Corrugating. -- A 9-point corrugating medium produced from a blend of Hawaiian fiber pulp, 85 percent, and waste kraft corrugating, 15 percent.
HFCX	Hawaiian Fiber Corrugating. -- A 9-point corrugating medium produced from Hawaiian fiber pulp, 100 percent.
HFL	Hawaiian Fiber Liner. -- A test liner board produced from a blend of Hawaiian fiber pulp, 50 percent, and virgin kraft pulp, 50 percent.
CC	Commercial Corrugating. -- A 9-point corrugating medium produced from a blend of commercial hardwood semichemical pulp, 85 percent, and waste kraft corrugating, 15 percent.
CL	Commercial Liner. -- A test liner board produced from Northern softwood kraft pulp.

The following commercial boards were used by the Robert Gair Company:

GC	Gair Corrugating. -- A commercial 9-point corrugating medium from waste paper.
GL	Gair Liner. -- A commercial test liner board from kraft pulp.

shipping. The Hawaiian Sugar Planters' Association shipped 2 tons of whole bagasse and 4-1/2 tons of depithed bagasse to Syracuse, N. Y. Preparation of fiber from Florida bagasse was done at Syracuse. For this purpose, 5 tons of "litter" grade bagasse were obtained from the United States Sugar Corporation, Clewiston, Fla. Three tons of bagasse containing all of its pith and dirt were also obtained. Both kinds of bagasse were dried before baling.

Separated fiber pulps for corrugating and liner boards were converted on the Fourdrinier section of the paper machine. In commercial manufacture of strawboard, Fourdrinier or cylinder wet ends are used on paper machines. Because of a desire for faster machine operation, the trend in the more modern mills has been toward use of Fourdrinier section; however, cylinder units are adapted to handle slow-draining pulps more readily than the Fourdrinier units. Furthermore, cylinder-machine board differs somewhat from board produced on Fourdrinier units. Therefore, it was planned to make corrugating board from whole bagasse pulp by both methods of machine formation. Because of difficulties in running the Florida whole bagasse pulps on the paper machine owing to their very poor drainage, it was decided not worthwhile to prepare pulps from whole Hawaiian bagasse.

Every paper machine has its own characteristics and each will make a paper of slightly different characteristics from the same pulp. For this reason, it was necessary to produce corrugating and liner boards from commercial wood pulps on the Syracuse paper machine as a control measure. For this purpose commercial semichemical pulp prepared from Northern hardwood was purchased for conversion into corrugating board and Northern softwood kraft pulp was purchased for making liner board.

Because of the large number of boards, it was necessary to develop code designations found in Table 4.

The contract with the New York College of Forestry included not only the pulping and paper-machine studies but also the operations of combining corrugating medium with liner boards to make "200-lb. test liner board" and manufacture of boxes. This combining operation and the subsequent operation of manufacturing boxes was subcontracted to the Robert Gair Company who operate a box plant in Syracuse, N. Y.

Technical representatives of the Northern Division, or of the Hawaiian Sugar Planters' Association were present as observers during all of the operations carried out under the contract. Complete reports were made on the different operations by the staff of the College of Forestry. The following discussion and data are taken largely from these reports with additional observations and test data by the Northern Division and Hawaiian Sugar Planters' Association observers as noted:

The depithing operations and pulping operations were carried out according to schedule developed at the Northern Division. These procedures were followed as closely as was possible when utilizing semi-commercial equipment.

Preparation of Separated Fiber from Florida Bagasse

The depithing operation consisted of the following steps:

1. Addition of water to Hydrapulper.
2. Heating of water to 80° C. and start of agitation.
3. Addition of bagasse to Hydrapulper.
4. Circulation of bagasse in Hydrapulper for 1 hour.
5. Dilution of stock in Hydrapulper for pumping.
6. Removal of pith over Jonsson vibrating screen.
7. Storage of depithed material for future operation.

Fiber for Corrugating Pulp

The Florida bagasse used for this operation consisted of 100 percent litter material. The depithing was divided into nine batches, each batch consisting of 400 lb. o.d. material. An amount of water in excess of actual requirements was added to the Hydrapulper and heated to 80° C. prior to the addition of bagasse. When the bagasse was thoroughly wetted, sufficient water was removed to adjust consistency of the charge to about 10 percent. Removal of the surplus water also aided in cleaning the bagasse. Operation of the Hydrapulper was continued for 1 hour. After this length of time the bagasse was diluted and pumped to the screen chest. The bagasse then passed over a Jonsson screen equipped with 1/4-inch perforations and the depithed material was removed from the end of the screen and stored. The effluent from the screen containing a large percentage of the pith was discarded.

Fiber for Liner Pulp

Raw material for this phase of the study consisted of 80 percent litter-grade bagasse and 20 percent whole bagasse. This combination was necessary as the litter material available at Syracuse was not sufficient for preparing the desired amount of separated fiber for liner board. Bales of the raw material were thoroughly broken up before the depithing treatment was started. It was found that the Hydrapulper did not have sufficient power to maintain circulation at the desired consistency, 7-8 percent. For this reason it was not possible to wet thoroughly the bagasse by feeding it into only sufficient water to give 7 percent consistency. A modified process was worked out whereby the bagasse was first thoroughly wetted, then the consistency raised for depithing.

1. An excess of water (approximately 600 gal.) was drawn into the Hydrapulper and heated to 80° C. by direct injection of steam. The condensation of steam added another estimated 100 gal. of water. The object of heating the water was to reduce the time required to wet the bagasse although this practice was contrary

to the general Northern Division process since it was known to cause a size reduction in liberated pith. In this instance, however, the pith was run to the sewer, hence its quality was not important.

2. The bagasse (approximately 440 lb., air-dry) was added rapidly and circulated for 15 minutes with steam injection continued to maintain the temperature at 80° C. At the end of the 15-minute period all of the bagasse appeared to be thoroughly wetted.

3. Excess water was drawn off through 3/32-inch-diameter perforations in the bottom plate of the Hydrapulper. Withdrawal was stopped when bagasse began to hold up along the sides of the pulper and block circulation. Although it was impossible to determine accurately the consistency at this stage, it appeared to be about 6 percent.

4. The Hydrapulper was operated for 40 minutes after the maximum consistency had been attained. Samples were taken from time to time to follow the depithing action and it appeared that no further removal of pith occurred after 40 minutes of circulation. In several of the runs additional water was drawn off after 20 or 30 minutes to compensate for the water entering through the packing gland.

5. The Hydrapulper charge was diluted to approximately 2-1/2 percent consistency and pumped to a storage chest with a 4-inch trash pump fitted with a screw feeder.

The depithed bagasse was wet-screened with a Jonsson screen of the same size as that tested at the Northern Division. Originally a screen plate having 1/8-inch perforations was used; however, too great an amount of large pith bundles remained with the fiber. Following the Northern Division experience, a screen with 1/4-inch perforations was installed and it worked satisfactorily. The consistency of screening could only be estimated as water was added in the stock chest, at the pump, and in the dilution box preceding the screen. The consistency appeared to be less than 0.5 percent. Screening of one charge took 40 to 50 minutes, the time being set to just keep up with the Hydrapulper and therefore to screen out as much of the pith as possible. The screening rate, 8 to 10 lb./minute, was 50 to 100 percent greater than that attained at the Northern Division and was possible only because dry-screened bagasse ("litter-grade") was used and the amount of pith to be removed was less.

The quality of this fiber in terms of amount of pith retained was just slightly below that produced at the Northern Division with the same Florida bagasse. Probably the fact that the operating consistency was less in the 8-foot Hydrapulper than in the 3-foot laboratory unit accounted for the difference in quality.

Table 5.--Conditions for semicommercial-scale production of experimental pulps from Florida and Hawaiian bagasse by the Mechano-Chemical Process for conversion to corrugating and liner boards at the College of Forestry, Syracuse, N. Y.

Conversion product Code designation		Corr. FFC	Corr. FWC	Corr. FWCC	Liner FFL	Corr. HFC	Corr. HFL
Digestion Stage							
Bagasse or fiber used,	O.D., lb.	2,400	2,800	2,556	3,800	4,725	4,320
Caustic Soda,	percent	12	10	11	16	12	16
Consistency,	percent	10	10	10	10	10	10
Temperature,	°C.	98	98	98	98	100	99
Time,	hr.	1.5	2.0	1.5	1.2	2.0	1.5
Yield:[1]	lb.	-	-	2,104	2,900	4,264	3,885
Basis original,	percent	-	-	82.5	38.0	-	-
Basis charge,	percent	-	-	82.5	76.5	90	90
Preliminary Refining							
Refiner setting:							
Ring,	inch/1,000	-6	-6	-8	-6	-5	-6
Plate,	inch/1,000	+13	+13	+13	+17	+10	+5
Freeness, C. S.,	ml.	452	252	360	452	-	-
Energy,	hp.-days/ton	8	9.8	3.6	4.0	6.1	7.1
Rate,	tons/day	-	-	-	-	37.7	32.3
Washing Stage							
Type		Beater	Beater	Decker	Decker	-	-
pH: Initial		11.4	11.5	10.5	11.2	12.3	12.5
Final		8	8	7.0	7.1	7.9	7.9
Wash yield:[1]	lb.	1,552	1.188	1,024	2,670	2,720	2,150
	percent	43.2	42.4	40.0	35.0	58	50

---

[1] Yield values are low because of opening sizes in screens available for these operations.

Preparation of Corrugating Pulps from Whole Bagasse and Separated Fiber

The digestion stage, that is, the actual pulping operation consisted of the following steps:

1. Addition of water to Hydrapulper.
2. Addition of chemical (sodium hydroxide) to Hydrapulper.
3. Heating of contents of Hydrapulper to 98° C.
4. Addition of bagasse (whole or depithed material).
5. Circulation of material in Hydrapulper for required time.
6. Draining excess liquor from Hydrapulper.
7. Dilution of contents in Hydrapulper for pumping.

The preliminary refining stage consisted of pumping the digested bagasse through a Sprout-Waldron refiner. This refiner was equipped with an adjustable retaining ring number 17709 and plates number 16964A (Rotor); 17637 (Stator). This preliminary refining served to break down fiber bundles with a minimum amount of actual refining.

Cooking of whole bagasse and depithed fiber was carried out in batches of 600 to 700 pounds in the 8-foot Hydrapulper in essentially the same manner in all cases. The requisite amounts of water and sodium hydroxide were heated to 98° C., then with the rotor in motion the bagasse or fiber sufficient for 10 percent consistency was added and the cooking continued for the necessary period of time. At the end of the cooking period the free liquid was drained from the Hydrapulper and fresh water added for displacement washing. Following this washing the charges were diluted to 2.5 percent consistency and pumped through the Sprout-Waldron refiner for a preliminary break. Stock from the refiner was pumped to a Jones-Bertrams beater or to a decker for washing. Sulfuric acid was added to assist in reducing the alkalinity of the pulp. Following washing the pulp was beaten to the desired freeness for use on the board machine or for blending with screened pulp from waste kraft cuttings. Pulps from Florida whole bagasse and Hawaiian separated bagasse fiber were screened over a 10-cut flat screen before the final refining step. Data pertaining to the cooking, preliminary refining, and washing of the pulps are presented in Table 5.

Preparation of Liner Pulps from Separated Fiber

Liner-board pulps were prepared from separated fiber of Florida and Hawaiian bagasse by essentially the same cooking and refining procedures as just described for the corrugating pulps. Batch size of the cooks ranged from 720 to 760 pounds of fiber. All washing was done with an underflow-type decker with an open white-water system. Sulfuric acid again was used to assist in reducing the alkalinity of the pulp. Pulp from the Hawaiian fiber was screened over a 10-cut flat screen before being refined to the desired freeness. The

Table 6.--Physical and chemical properties of Florida and Hawaiian bagasse pulps prepared in an 8-foot Hydrapulper by Mechano-Chemical Process and wood pulps used in board furnishes at Syracuse, N. Y.

Code	Material W = Whole F = Fiber Year - Variety	Cooking conditions			Type furnish	Chemical analysis[2]			Initial freeness S.-R.	Strength characteristics 500 ml. S.-R.				
		Chemical[1]	Time	Temperature		Ash	Lignin	Pentosans[3]		Basis weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Riehle ring crush[4]
		%	hr.	°C.		%	%	%	ml.	lb.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb. x 100	lb.
FWC	Clewiston, Fla. W Fresh 1952 F.31-436	12 NaOH	1.5	99	Corrugating	0.66	7.4	34	710	119	96	163	78	36
FFL	Clewiston, Fla. F Fresh 1952 F.31-436	16 NaOH	1.2	99	Liner	.60	7.8	34	820	118	111	182	80	35
HFC	Oahu, Hawaii F Fresh 1952 8560	12 NaOH	2.0	99	Corrugating	1.03	11.7	33	845	119	90	161	86	34
HFL	Oahu, Hawaii F Fresh 1952 8560	16 NaOH	1.5	99	Liner	-	-	-	865	120	94	164	94	36
CC	Commercial semi-chemical corrugating pulp	-	-	-	Corru-	1.5	14.9	22	605	118	83	148	79	31
CL	Commercial southern kraft liner pulp	-	-	-	Liner	1.0	7.1	13	890	116	133	192	197	31

---

[1] Basis oven-dry raw material.

[2] Basis oven-dry screened pulp.

[3] Pentosans = furfural x factor 0.8.

[4] 2-Inch specimens.

screened pulp was blended with an equal amount of virgin kraft pulp previously beaten to 650 ml. C.S. Pulp from Florida fiber was prepared for the board machine directly from the refiner without screening alone or in blends with the virgin kraft pulp. Data pertaining to cooking, preliminary refining, and washing are given in Table 5.

Discussion of Pulping Operations

The operating data relating to the preparation of two corrugating pulps from whole Florida bagasse; one corrugating pulp and one liner-board pulp from Florida depithed fiber; and two types of pulp from depithed Hawaiian bagasse, e.g., corrugating and liner-board pulps, are presented in Table 5.

Samples of pulps prepared in Syracuse were shipped to Peoria and evaluated by the Pulping and Mechanical Processing Unit for comparison with results obtained on similar pulps prepared in the 3-foot laboratory-size Hydrapulper. Results of pulp evaluations carried out at the Northern Division are presented in Table 6.

The following comments and observations concern the pulping operations with bagasse and bagasse fiber:

Since bagasse is a very free material it tends to release water rapidly and float on the surface. However, by thoroughly wetting small particles this difficulty can be minimized. Normal precautions should be taken when designing slush-handling equipment so that the pipelines will be of sufficient size, definitely not less than 8 inches in diameter, to insure a continuous flow of the material. These pipelines should be free from sharp bends and have a minimum number of valves. Although no difficulties were encountered in pumping the cooked bagasse, it would be advisable to have an open impeller pump similar in construction to the old type fan pump or a bladeless impeller pump such as that manufactured by Fairbanks-Morse. A continuous recirculating line should be provided above the refiners used in the preliminary refining stage so that the stock could flow around the circuit and allow the required amount to be bled off for optimal refiner operation.

The presence of alkali-soluble material in bagasse results in excessive foaming after digestion with sodium hydroxide. It was found necessary to use a defoaming agent such as Nopco KFH in all pulp slurries being washed. This material practically eliminated the foam and facilitated washing. The subsequent screening operation was carried out with a minimum of foaming difficulty.

No difficulties were encountered when screening the pulp over a Jonsson vibrating screen. However, an extremely long period of time was required to screen on a flat screen, and it is our opinion that a vibratory screen such as the Jonsson-Lingren would facilitate this operation.

The yields, reported in Table 5, for the boards manufactured from whole Florida bagasse are lower than the values anticipated as a result of the preliminary experiments at the Northern Division. The lower yield values are due to three factors: (1) The whole bagasse had a high percentage of very fine particles; (2) appreciable quantities of field dirt and gritty particles; and (3) washing over a decker with an open system to remove pith particles for efficient machine operation. Tests indicated that 90 pounds of solids were lost in the effluent during the first washing stage and 16 pounds of solids were lost in the effluent during the second. These quantities represent a loss of 14 percent in the first washing stage and 3 percent in the second washing stage. Beater washing was much slower and less efficient than the decker washing.

The preliminary refining of the bagasse pulps was carried out without any difficulty. The action of the Sprout-Waldron disc mill was sufficiently active to separate the fiber bundles without an excessive reduction in freeness.

The depithed cooked Hawaiian bagasse after washing had a high freeness value. This pulp appeared somewhat brash and required over 1 hour for beating at 4,000 pounds pressure in the Jones-Bertrams beater. This time was in excess of that required for the Florida bagasse and may be due to a naturally more harsh fiber or to a slight degree of undercooking. In all probability this could be eliminated in commercial production.

The yield reported in Table 5 for the boards manufactured from the depithed Florida and Hawaiian bagasse is also slightly lower than the values anticipated as a result of preliminary experiments at the Northern Division. For example, the yield of corrugating pulp from Hawaiian fiber amounted to 58 percent of the depithed material and that of liner pulp from Hawaiian fiber amounted to 50 percent. The lower yield values which were obtained at Syracuse are in all probability due to a very thorough washing of the cooked pulp over the underflow-type decker, particularly when an open white-water system was used. Experience has indicated that it was necessary to wash the pulp thoroughly to facilitate the removal of the fine pith particles which tend to slow the stock suspension on the wire and are detrimental to efficient machine operation.

The pulping of the Florida whole bagasse was carried out using more chemical than originally appeared necessary in preliminary runs and the pulps in some instances were improved somewhat. However, it is believed that improvements made were due chiefly to the removal of fines from the pulps which resulted in lower yields. The removal of fines from the whole bagasse pulp resulted in what might be considered a chemically depithed bagasse. A comparison of the physical tests and freeness (Table 6) would indicate this to be true.

The pulps prepared in the 8-foot Hydrapulper from the Florida fiber were also freer than those prepared previously, indicating the decker used in washing was removing more of the fines from the pulp than laboratory methods of washing. The strengths of the pulps prepared on the larger scale for both corrugating and liner board from the Florida bagasse were quite similar to strengths of pulps prepared on a laboratory scale.

The pulps prepared in the 8-foot Hydrapulper from the Hawaiian bagasse were slightly better than those prepared in a 3-foot Hydrapulper but in lower yields and with larger amounts of pulping chemical. The loss in fines which improved the machine operation in preparing these boards did not noticeably change the majority of the physical strength properties.

The test data on the pulps would indicate that even though some of the pulps prepared at Syracuse were not refined to optimum strength the characteristics of these pulps were essentially of the same order as those prepared in laboratory equipment at Peoria.

SEMICOMMERCIAL-SCALE CONVERSION OF PULPS INTO CORRUGATING AND LINER BOARDS

Conversion of Experimental Pulps to Board

Conversion to Corrugating Media on Fourdrinier Machine

Beaten bagasse pulps together with the necessary amounts of other fibrous materials, depending upon the composition of the run, were placed in the paper-machine stock chest before the run began and thoroughly blended. The stock was pumped from the stock chest to the stuff box, through the jordan to a mixing box where it was blended with white water from the paper machine and from there to the headbox of the paper machine. The stock was formed in the usual manner on the paper machine passing from the wire to the presses through the driers and calender stack to the reel. The reels of board were rewound into rolls of size suitable for use in the box shop. Nopco KFH in dilute solution was used at the press rolls to prevent sticking of the wet webs.

The blend of refined pulp (freeness 160 ml. C.S.) from Florida whole bagasse and 15 percent of repulped waste kraft cuttings was run on the machine at a freeness of 213 ml. C.S.

Extreme difficulty was encountered in attempting to remove the wet web from the first press and it was practically impossible to make a satisfactory sheet from this material. It was therefore deemed advisable to stop operations and rewash the entire batch over the decker to remove some of the fines. Approximately 9 percent of

Table 7.--Operating data on conversion of bagasse pulps into corrugating medium and liner board

Conversion product Code designation	Corr. FFC	Corr. FWC	Corr. FWC-1	Corr. FWCC	Corr. FFL	Corr. FFLX	Corr. FFLY	Corr. HFC	Corr HFCX	Corr HFL
Refining Stage										
Beater charge, O.D., lb.	1,552	1,188		1,024	1,530	868		2,070		2,150
Consistency, percent	6.8	5.5		4.7	6.0	4.9		5.6		5.2
Time of beating, hr.	0.83	0.25		0.1	0.8	0.3		1.1		1.18
Energy, hp.-days/ton	8	1.8		2.9	7.2	3.7		13.8		2.02
Freeness, C.S.										
Initial, ml.	438	237		344	450	463		596	596	651
Final, ml.	250	160		250	232	363		260	292	218
Paper Machine Operation										
Run No.	A-1	B-1	B-2[1]	F-1	E-2	E-1	E-3	G-2	G-1	H-1
Pulp to machine chest, O.D.										
Bagasse, lb.	1,552	1,188	716	1,016	1,530	868	400[2]	2,070	650	2,150
Waste kraft cuttings, lb.	227	227	167	221	-	-	-	345[3]	-	-
Virgin softwood kraft, lb.	-	-	-	-	1,530	-	400	-	-	2,133
Freeness, C.S.										
Virgin softwood kraft, ml.	-	-	-	-	650	-	545	-	-	651
Machine chest, ml.	254	213	-	344	460	363	485	248	245	397
Headbox, ml.				320	380	340	385	246	188	322
White-water system	open	open		closed	closed	closed	closed			
pH, white-water system	6.9-7.8	6.2	6.2	7.0	7.5	7.0	7.0	7.2	7.2	7.2
Consistency										
Machine chest, percent	2.6	2.4	2.3	1.87	2.6	2.6	2.6	2.58	2.4	2.88
Headbox	0.90	0.95	0.90	-	0.68	0.70	0.70	1.04	1.25	1.15
Machine speed, ft./min.	110	68	68	65	65	56	65	72	68	72
Quantity of board produced, lb.	1,005		496	773	2,435	266	757	2,037	461	3,450

---

[1] Pulp from B-1 washed over decker to remove fines; 8.9 percent removed.

[2] This is FFL (Florida fiber and virgin kraft, 50:50).

[3] 345 lb. O.D. waste kraft - 7½ hr./180° C. in Hydrapulper and then screened.

the furnish was removed as fines by this washing treatment. The rewashed stock was then run on the paper machine to produce corrugating medium FWC-1. Although pulp appeared somewhat freer, it was still rather difficult to remove the wet web from the first press. Slight surface picks were in evidence across the entire sheet during the remainder of the run. However, 496 pounds of this material was made into 9-point board for corrugating.

After an initial attempt to run a blend of refined pulp (freeness 250 ml. C.S.) from Florida separated fiber and 15 percent repulped waste kraft cuttings, the furnish was removed from the stock chest and screened through a 10-cut flat screen. This operation removed grit and lumps. Satisfactory board (FFC) was made from the screened stock. Alum was added at the stock chest during this run to maintain the pH value of the stock at about 7.

A machine run with only refined pulp from Hawaiian separated fiber was tried at a freeness of 292 ml. C.S.; however, a more satisfactory board (HFCX) was produced after additional jordaning to a freeness of 188 ml. C.S. Finished corrugating amounting to 461 pounds was prepared. Pulp from the Hawaiian separated fiber was also blended with repulped waste kraft cuttings and run on the Fourdrinier without difficulty to produce 2,037 pounds of 9-point board containing 85 percent pulp from separated fiber.

Data pertaining to digestion, preliminary refining, and washing are given in Table 5, while data on refining, blending, and machine operation are given in Table 7.

Conversion of Pulp to Corrugating Media on Cylinder Machine

Pulp used for this run was prepared from Florida whole bagasse. Conditions of the digestion and preliminary refining stages were identical with those for the Fourdrinier run with Florida whole bagasse. These data have been presented in Table 5. Subsequently the pulp was thickened on a Jonsson screen and washed over an underflow decker. This was more effective than beater washing. The decker was operated with fresh water and an open system. After the first wash, sulphuric acid was added to reduce the pH to a value of 9 and the entire charge was then rewashed over the decker. After washing, the bagasse pulp was pumped to the beater for refining. The pulp was beaten from an initial freeness of 344 ml. C.S. to a final freeness of 250 ml. C.S. The pulp was then screened to remove undesirable grits, field dirt, and lumps. The screened stock was then pumped to the beater chest. Pulp from waste kraft cuttings was also added to this chest to the extent of 15 percent of the final blend.

The stock was then pumped to the cylinder-machine stock chest and from there through the stuff box to the mixing boxes where white water was added for dilution and then to each of three vats of the cylinder machine. The stock passed from the vats to the baby presses, primary presses, and main presses, to the drier section, through the calender stack and to the reel. Reels of 9-point board were rewound into rolls of size suitable for use in the box shop. The stock appeared to make a very closed sheet and blowing was very noticeable both at the top couch nip and just before the baby presses. It was found necessary to remove all excess weights and in some instances to relieve the top couch roll and baby presses in order to prevent compacting the sheet, thereby allowing the air to escape through the sheet more readily. Excessive sticking was in evidence during this run. Due to the elimination of practically all press weights the sheet was somewhat difficult to dry and drier felt marks were in evidence in the finished paper (FWCC) throughout the run. Sufficient paper was made for conversion tests. Data pertaining to this machine run are shown in Table 7.

Conversion of Pulp to Liner Board on Fourdrinier Machine

Pulp from Florida separated fiber was used in the preparation of corrugating of three formulations. One (FFLX) consisted of 100 percent of fiber pulp refined to a freeness of 363 ml. C.S. Some sticking was in evidence when this stock was run on the Fourdrinier in the usual manner. Other formulations included 50 percent (FFL) and 25 percent (FFLY) blends of fiber pulp with virgin kraft pulp. These stocks were run over the Fourdrinier machine without difficulty and very acceptable liner boards were produced.

The refined pulp (freeness 218 ml. C.S.) from Hawaiian separated fiber and the virgin kraft pulp were blended together in equal parts. The resulting stock in the machine chest had a freeness of 397 ml. C.S. and was further refined in the jordan to a headbox freeness of 322 ml. C.S. It was converted into liner board (HFL) (3,450 pounds) without difficulty.

Data pertaining to the preparation and conversion of these stocks are presented in Table 7.

Discussion of Board Machine Operations

Florida Pulps

Semicommercial-scale production of bagasse corrugating media and liner boards on the Fourdrinier and cylinder paper machines was carried out successfully. The whole bagasse pulps were very slow on the machine wires. This is characteristic of all bagasse pulps containing the original pith. This slow characteristic is due in part to the presence of small quantities of pith which tends to form a "closed" sheet. Evidence of this was noted in the high vacuum drawn by the suction couch (17.5 inches). Normal operation of the machine with similar weights of paper results in a vacuum of less than 14 inches. Further evidence of the presence of pithlike material was borne out by excessive sticking of all the papers containing approximately 85 percent pulp from whole bagasse in their furnish. When kraft pulp was blended with bagasse pulp to the extent of 50 percent, the pithlike material was dispersed, and practically all of the stickiness disappeared from the sheet.

In the case of a cylinder machine run for the production of corrugating medium (FWCC), from Florida whole bagasse, the dense packing effect of the pithlike material prevented rapid passage of air through the sheet. This resulted in "blows," that is, the trapping of air between the layers built up on each of the three vats. Relief at the press and couch rolls decreased the amount of pressing and minimized the packing effect, allowing the sheet to become more porous and permitting the air to escape.

Under the conditions at which the paper machine of the College of Forestry operates, it appears that a furnish consisting of a blend of bagasse and waste papers would prove suitable for commercial operation. A furnish of not more than 75 percent bagasse and 25 percent waste papers should produce a very satisfactory corrugating medium. The inherent stiffness quality of the bagasse fiber should result in a sheet having more than the minimum crush test even though only 50 percent of the fiber furnish was bagasse.

Hawaiian Pulps

The production of corrugating medium and test liner board on the Fourdrinier paper machine was carried out successfully. The corrugating bagasse pulps were somewhat slow on the wire and tended to stick on the press rolls. The presence of fine particles such as pith tends to react in this manner on the wire of a paper machine. However, instead of using a 70-mesh wire such as is used on the paper machine at Syracuse, a 40-mesh would be more appropriate. This would allow a higher percentage of fines to be returned to the white water and be circulated within the system. The rapid drainage of these fines through the wire facilitates the drainage characteristics of the sheet and allows faster machine operation. The sticking of the sheet to the top press roll was eliminated by the use of a dilute solution of Nopco KFH applied continuously to the top press roll.

When virgin kraft pulp was added to the bagasse to prepare a 50-percent blend for the manufacture of test liner board (HFL), the sheet drained more readily and all sticking on the first press was eliminated. The entire run was made without trouble.

It is our opinion that a furnish consisting of a blend of bagasse and waste papers would be suitable for manufacture of a corrugating medium. Under the conditions of machine operation, it was possible

Table 8.--Operating data on conversion of commercial semichemical hardwood pulp and virgin kraft pulps into corrugating medium and liner board, respectively

	CC	CL
Refining Stage		
Beater charge, O.D., lb.	1,440	2,400
Consistency, percent	5.9	5.5
Roll weight, lb.	4,000	6,500
Time of beating, hr.	0.17	0.82
Energy, hp.-days/ton	2.17	15.5
Freeness, C.S.		
Initial, ml.	425	735
Final, ml.	325	563
Paper Machine Operation		
Run No.	C-1	D-2
Pulp to machine chest, O.D.		
Semichemical pulp, lb.	1,440	-
Waste kraft cuttings, lb.	215	-
Virgin softwood kraft, lb.	-	2,400
Freeness, C.S.		
Virgin softwood kraft, ml.	325	-
Machine chest, ml.	-	563
Headbox, ml.	301	380
pH, white-water system	7.8	8.0
Jordan	-	heavy
Consistency		
Machine chest, percent	2.7	2.7
Headbox, percent	0.86	0.63
Machine speed, ft./min.	76	74
Quantity of board produced, lb.	1,156	1,999

to produce a satisfactory corrugating medium utilizing 85 percent depithed Hawaiian bagasse and 15 percent waste kraft cuttings. There is sufficient inherent stiffness in bagasse to allow the furnish to be made up of a lesser quantity of this fiber. However, the exact percentage will have to be determined by the design of the paper machine and the availability of waste paper. The test liner board containing 50 percent bagasse met the minimum requirements for the type of box that would be fabricated from it. Since this blend ran exceptionally well on the paper machine, it is to be assumed that no difficulties would be encountered in commercial operation.

Conversion of Commercial Pulps to Corrugating and Liner Boards

In order to establish a basis for comparison it was deemed advisable to convert standard semichemical corrugating pulp and standard virgin kraft pulp into 9-point corrugating medium and test liner board, respectively. The standard semichemical pulp was purchased from the Green Bay Paper and Pulp Company and the virgin kraft pulp from McIntyre Bros. Paper Company. The kraft pulp was originally manufactured by the Camp Manufacturing Company of Franklin, Va. The kraft pulp is the same material that was used to make the blends with the bagasse liner pulp, the preparation of which has been described earlier (FFL, FFLX, and HFL).

Hardwood Semichemical Corrugating Medium

The semichemical pulp laps were disintegrated in the Hydrapulper and refined in the Jones-Bertrams beater. This pulp had an initial freeness of 425 ml. C.S. and was beaten to a final freeness of 325 ml. C.S. Waste kraft cuttings thoroughly disintegrated in the Hydrapulper were added in the amount of 15 percent to the machine chest and thoroughly blended with the semichemical pulp. This was run over the paper machine and made into 9-point corrugating medium. The semichemical pulp formed very well on the wire and no difficulties were encountered throughout the entire run. All data pertaining to this run are presented in Table 8.

Softwood Kraft Liner

The virgin kraft pulp laps were thoroughly disintegrated in the Hydrapulper and pumped to the beater for refining. This pulp was refined from an initial freeness of 735 ml. C.S. to 563 ml. C.S. The sheet formed very well on the paper machine, and no difficulties were encountered throughout the entire run. In this particular instance the jordan was used very heavily so that the freeness of the stock was reduced from 563 ml. C.S. in the stock chest to 380 ml. C.S. in the headbox. The specific data for this run are available in Table 9.

Table 9.--Physical properties[1] of semicommercial corrugating and test liner boards from Florida and Hawaiian bagasse, commercial pulps, and commercial papers

	FFC	FWC	FWCC	FFL	FFLX	FFLY	HFCX	HFC	HFL	CC	CL	GC	GL
Machine run	A-1	B-2	F-1	E-2	E-1	E-3	G-1	G-2	H-1	C-1	D-2		
Basis weight													
25 x 40-500	113.2	107.8	114.0	154.7	143.8	152.3	128.0	96.0	152.3	111.3	139.9	136.0	152.6
24 x 36-500	97.8	93.1	98.5	133.7	124.2	131.6	110.4	83.0	131.6	96.2	120.9	117.5	131.8
Per 1,000 sq. ft.	32.6	31.0	32.8	44.6	41.4	43.9	36.8	27.7	43.9	32.1	40.3	39.2	43.9
Caliper (mill)	8.4	10.0	10.0	11.2	9.5	10.9	11.2	8.9	14.0	10	11	10.9	13.1
Bulk factor (cc./gm.)													
25 x 40-500	1.27	1.56	1.48	1.30	1.18	1.28	1.50	1.56	1.52	1.55	1.40	1.40	1.55
24 x 36-500	1.47	1.81	1.72	1.51	1.37	1.49	1.74	1.81	1.76	1.80	1.62	1.63	1.79
Tear factor (gm./lb.)													
Machine direction													
25 x 40-500	0.98	0.97	0.82	1.59	0.98	1.99	0.92	1.00	1.83	0.93	2.18	1.27	2.54
24 x 36-500	1.13	1.12	95	1.84	1.13	2.30	1.06	1.15	2.11	1.07	2.52	1.47	2.94
Cross direction													
25 x 40-500	1.12	1.24	1.41	1.75	1.08	2.23	1.10	1.27	2.01	1.23	2.47	2.01	2.92
24 x 36-500	1.30	1.44	1.64	2.02	1.25	2.59	1.28	1.47	2.33	1.43	2.85	2.32	3.38
Burst factor (pt./lb.)													
25 x 40-500	0.63	0.68	0.73	0.81	0.73	0.75	0.72	0.78	0.69	0.71	0.85	0.40	0.72
24 x 36-500	0.73	0.79	0.84	0.93	0.85	0.87	0.83	0.91	0.80	0.82	0.99	0.47	0.83
Tensile strength (kg.)													
Machine direction	16.9	17.5	24.5	27.7	23.0	26.2	19.9	16.2	22.2	20.2	26.9	16.3	23.0
Cross direction	11.0	9.7	9.1	14.5	14.9	13.7	12.7	8.3	14.2	9.6	11.2	4.2	12.7
Stretch (percent)													
Machine direction	2.8	2.9	3.4	3.8	3.7	3.4	3.3	3.0	2.7	2.5	3.6	2.3	3.1
Cross direction	4.6	3.7	3.3	5.3	5.7	6.8	5.0	4.2	5.1	3.5	6.4	3.0	4.8
Stiffness (Smith-Taber)													
Machine direction	29	30	30	54	41	49	40	25	62	37	49	46	64
Cross direction	27	24	22	38	33	37	27	24	45	26	28	24	42

---

[1] Tested at TAPPI Standard Conditions, 73° F., R.H. 50 percent.

Physical Properties of Corrugating and Liner Boards

The physical properties of the experimental media and test liner boards produced at the College of Forestry and the commercial corrugating medium and liner board used by the Robert Gair Company at their Syracuse, N. Y., plant were determined by both the College and the Northern Division. Results of these tests are presented in Tables 9 and 10, respectively.

Corrugating Media

The basis weight values of the corrugating media prepared from Florida bagasse are slightly lower than that of Robert Gair commercial corrugating medium. However, in all instances the caliper was maintained between 8 and 10 mils. The bulk factor values (cc./gm.) are generally lower for the media containing bagasse than for the control medium produced from commercial semichemical pulp and for that manufactured for Robert Gair. However, these differences are relatively slight and should not affect the operation of converting equipment. Tear factors (gm./lb.) in both the machine and cross direction were considerably lower than in Robert Gair's corrugating medium. This difference in all probability is due to the presence of kraft pulp in the commercial material. Tear values of the experimental bagasse media compare very favorably in both the machine and cross direction with that of the control corrugating medium which was prepared at the College from semichemical pulp. The cylinder machine-made corrugating medium (FWCC) had the higher tear value in cross direction of the machine.

The burst factor (pt./lb.) showed a decided advantage for all of the boards produced at the College when compared with Robert Gair's material, the burst factors being almost double that of the commercial material. The paper made from bagasse compares very favorably with that prepared from the semichemical pulp. The tensile strengths (kg.) follow the characteristics of the burst factor very closely, and these are equal to or better than either the commercial material or the semichemical corrugating medium. The bagasse boards also show to advantage in the amount of stretch in both the machine and cross direction. This property should be advantageous in the formation of the flutes during converting. Due to the inherent stiffness of bagasse, the corrugating medium containing this material had a "snappy" feel and showed to considerable advantage when compared with either the commercial corrugating medium or the semichemical corrugating medium. Undoubtedly the stiffness tests would have been higher if the pulps had been freer, allowing greater pressing and more compacting of the sheet. The basis weights of the corrugating media prepared from Hawaiian bagasse and hardwood semichemical pulp are slightly lower than that of Robert Gair's commercial corrugating medium. However, in all instances the caliper was maintained between the limits of 8 and 11 mils. The corrugating medium (HFC) prepared

Table 10.--Physical characteristics of corrugating and liner boards prepared experimentally from Florida and Hawaiian bagasse pulps and commercial pulps, and boards of commercial manufacture

Code designation	Basis weight		Caliper	Strength characteristics							
				Bursting strength		Tearing resistance		Tensile strength		Riehle ring crush[1]	
	1,000 sq. ft.	25x40-500				MD	CD	MD	CD	MD	CD
	lb.	lb.	inches/1,000	lb./sq. in.	pt./100 lb.	g./ream-lb. x 100		g./ream-lb.		lb.	lb.
FFC	29.7	103	8.3	73	71	98	105	143	102	31	22
FWC	34.0	118	10.0	73	62	89	99	159	98	43	35
FWCC	32.7	113	9.4	101	89	81	120	226	78	40	25
FFLX	41.3	143	9.8	121	85	90.2	94	167	110	40	36
FFL	42.7	148	11.0	148	88	166	218	188	91	40	29
FFLY	37.0	129	9.6	125	97	195	191	189	92	37	27
HFCX	33.1	115	9.8	79	68	91	96	170	104	39	31
HFC	30.5	106	8.8	78	74	104	115	165	95	32	24
HFL	44.7	155	12.7	125	81	170	221	164	94	54	40
GL	43.0	149	13.2	131	88	262	313	158	86	32	26
GC	41.3	143	11.0	75	53	127	199	143	33	32	18
CL	39.7	138	10.6	138	100	212	272	191	80	39	26
CC	30.3	105	9.2	73	70	92	111	168	99	35	24

---

[1] 2-inch specimen.

from a blend of 85 percent depithed Hawaiian bagasse and 15 percent waste kraft cuttings was appreciably lower in weight but had sufficient bulk to caliper 8.9 mils. The bulk factor (cc./gm.) was higher for all of the corrugating media prepared at the College than for the commercial product. Media containing Hawaiian bagasse were essentially equal in bulk factor to the medium prepared from commercial semichemical pulp. The medium (HFCX) prepared from a furnish of 100 percent Hawaiian bagasse fiber pulp had a lower bulk factor than the medium (HFC) prepared from a furnish of Hawaiian bagasse fiber, 85 percent, and waste kraft cuttings, 15 percent. In all instances the tear factor (gm./lb.) of the pulps manufactured at Syracuse were lower than the Robert Gair commercial corrugating medium. The burst factor of the corrugating medium produced at Syracuse was definitely superior to the commercial product and equal to or better than the values obtained for the 9-point control (CC) produced at the College from commercial hardwood semichemical pulp. Only slight variations in tensile strength and stretch were noticed in the test values of all boards tested. However, the stretch values are all in favor of the medium containing Hawaiian bagasse.

Liner Boards

Basis weights of Gair commercial liner and of the experimental test liner boards prepared from Florida bagasse, blends of bagasse and kraft pulp, and 100 percent kraft pulp are relatively close. The caliper (mils) is somewhat higher for the commercial liner than for those prepared at the College. The reason for this, in all probability, is due to the fact that all paper furnishes prepared at the College were refined to lower freeness values than one would expect in commercial-paper furnishes used on high-speed machines. This difference is also indicated in the test for bulk factor (cc./gm.), the exceptionally high tearing strength of the commercial liner and the lower bursting strength. In all instances the tear factor of the liner boards containing bagasse are appreciably lower than either the commercial liner board or the material prepared at the College from kraft pulp. The tear values of the board (FFLY) containing 75 percent kraft and 25 percent bagasse more closely approached values of the control (CL) from the commercial kraft pulp than did the values for other boards containing bagasse.

The burst factor (pt./lb.) of all liner board produced at the College was equal to or better than the commercial liner used by Robert Gair. The board (FFL) prepared from 50 percent bagasse and 50 percent virgin kraft showed the highest test of all boards containing bagasse and was almost equal to the control liner (CL) prepared at the College from 100 percent virgin kraft pulp. The tensile strength (kg.) and stretch values were equal to or better than those obtained for the Gair liner and very closely approached, or were equal to, those of the control liner produced at the College. The inherent stiffness characteristic of bagasse is in evidence in the feel of the liner board as it was in the corrugating medium.

The basis weights of Gair commercial liner and of the test liner boards produced from 100 percent kraft pulp and from blends of bagasse and kraft pulp are within the specifications and are relatively close. The caliper of all these boards is less than 16 points, the highest being 14 mils for liner (HFL) prepared from a blend of 50 percent depithed Hawaiian bagasse. The bulk factor was slightly lower for the above board and for the test liner prepared from 100 percent kraft pulp. The tear factor (gm./lb.) was lower for the bagasse blend than for the 100 percent kraft sheet and this in turn was lower than for the Gair liner. The reason for this in all probability is due to the fact that the paper furnishes prepared at the College were refined to lower freeness values than one would expect in commercial-paper furnishes used on high-speed machines, and also due to the fact that the bagasse fiber itself does not have the high tearing-strength values of kraft pulps. The burst factor (pt./lb.) of the furnish containing bagasse was lower than that of the 100 percent kraft liner board or of the Robert Gair commercial liner. However, this value was sufficient to meet the minimum requirements for test liner board. The tensile strength, percent stretch, and stiffness of the liner board produced from the bagasse-kraft furnish were equal to or better than those of the commercial liner, and the stiffness was higher than that of the control test liner produced at Syracuse from 100 percent kraft pulp. This higher stiffness value is in all probability due to the inherent stiffness characteristic of bagasse.

Results of tests made on the corrugating media prepared at Syracuse would indicate that these boards were of higher quality than that of the average corrugating presently on the market. On a weight basis the bursting strength of the experimental corrugating was equal to many of the kraft liners commercially available with a somewhat lower tearing resistance. The tearing resistance does not, however, appreciably affect the quality of the corrugating medium. The Gair corrugating medium used as a comparison was considerably heavier than normally used and the bursting strength (p.s.i.) was quite similar to boards prepared from bagasse. The weight factor would also increase the crush resistance of this board. The variations in the weight of the experimental corrugating boards are such as might be normally anticipated when a limited quantity of each pulp is available for machine runs.

The liner boards prepared had reasonably good bursting strength with variations in the weight of the board. The heavier weight boards (FFL and HFL) would be expected to provide higher bursting strength in the finished boxes than board (FFLY) which was of a somewhat lower weight but had higher bursting strength per unit of weight.

The liner (CL) prepared from the kraft pulp at the College was of unusually good quality from a strength viewpoint and was probably due to greater than normal refining of this pulp prior to going onto the paper machine. With the exception of the liner (FFLX) prepared from 100 percent bagasse, all the boards prepared from the blends of bagasse appeared to meet the minimum requirements for strength.

The paper machine production for the boards made is given in Table 11.

COMBINING OPERATIONS AND CONTAINER FABRICATION IN A COMMERCIAL BOXSHOP

Combining and Fabrication

The corrugating, combining and box manufacturing operations involving the experimental and control boards were carried out under subcontract with the Robert Gair Company, Syracuse, N. Y. The Gair Company made every effort to expedite this work in the best possible manner, and to schedule combining and fabricating operations without interference from normal commercial production. Box sizes and quantities to be produced were specified in accordance with the trimmed width of the experimental boards and with shipping tests contemplated by the Hawaiian Sugar Planters' Association and the Northern Division.

Nevertheless it must be recognized that in the combining and boxmaking operations it always takes some time to make all of the adjustments on the machines that are required to produce the most perfect boards and boxes to specifications. Each material behaves in a different manner to corrugating, scoring, pasting, and stapling. The amounts of materials were strictly limited and a large number of combinations were indicated; consequently, a number of boxes made showed imperfections.

The combining schedule of the Gair Company is shown in Table 12.

After the combining operation the test liner boards were made into boxes of three different sizes as shown in Table 13. The boxes were printed with the code numbers, showing the type of test liner board from which the box was made, and the certificate stamp of the Robert Gair Company, the boxmaker. The printing, cross-scoring, and stapling of the boxes were carried out using the Gair standard commercial equipment with a minimum of difficulty. The finished boxes were shipped to the Northern Division for distribution and testing.

Strength Characteristics of Combined Boards

The bursting strengths of all combined boards were equal to or better than 200 lb. per square inch with the exception of the liner board (FFLX) prepared from 100 percent Florida bagasse pulp. The bursting strengths of the various combined boards are reported in Table 14.

Table 11.--Quantities of the various corrugating and liner boards produced in semicommercial machine operations at the College of Forestry, State University of New York, Syracuse

Board	Machine run No.	Lb. produced
FFC	A-1	1,005
FWC	B-2	496
FWCC	F-1	773
CC	C	1,156
FFLX	E-1	226
FFL	E-2	2,435
FFLY	E-3	757
CL	D-2	1,999
HFCX	G-1	461
HFC	G-2	2,037
HFL	H-1	3,450

Table 12.--Composition of double-faced container board and quantities (40-inch width) produced in commercial-scale operations at the Robert Gair Company, Syracuse, N. Y.

Combination, code designations	Lineal ft.	Run No.
FFL - CC - FFL	1,100	C
FFL - FWC - FFL	1,100	B-2
FFL - FFC - FFL	2,200	A
FFL - FWCC - FFL	2,200	F
FFL - GC - FFL	1,100	Robert Gair
CL - CC - CL	1,100	C
CL - FWC - CL	1,100	B-2
CL - FFC - CL	1,100	A
CL - FWCC - CL	2,200	F
CL - GC - CL	1,100	Robert Gair
GL - CC - GL	1,100	C
GL - FWC - GL	1,100	B
GL - FFC - GL	2,200	A
GL - FWCC - GL	2,200	F
GL - GC - GL	2,200	Robert Gair
FFLX - GC - FFLX	800	E-1
FFLY - GC - FFLY	1,500	E-3
GL - HFCX - GL	2,000	G-1
GL - HFC - GL	5,000	G-2
HFL - HFC - HFL	4,500	H-1, G-1, H-1
HFL - CC - HFL	2,500	H-1, C-1, H-1
HFL - GC - HFL	3,000	H-1, GC, H-1
CL - HFC - CL	3,000	G-2

- - -

Table 13.--Types, symbols, and dimensions of shipping containers fabricated from experimental, control, and commercial corrugated boards

Container type	Symbol	Dimensions, inches
Single tier, 211 x 414 can, "flat juice"	FJ	16-1/4 x 10-13/16 x 4-7/8
Double tier, 211 x 414 can	DT	10-3/4 x 8-1/16 x 9-3/4
Tall bottle	TB	16-5/8 x 11-1/32 x 8-1/16

Table 14.--Bursting strengths of double-face corrugated container boards produced from experimental, control, and commercial materials in a commercial box shop. (Tests by the College of Forestry, State University of New York, Syracuse)

Liner board		Corrugating media		
Code	Bagasse content	Code	Bagasse content	Burst
	percent		percent	lb./sq. in.
HFL	50	HFC	85	210
		CC	-	200
		GC	-	210
FFLY	25	GC	-	200
FFL	50	FFC	85	240
		FWC	85	240
		FWCC	85	210
		CC	-	260
		GC	-	200
FFLX	100	GC	-	150
CL	-	FFC	85	230
		FWC	85	240
		FWCC	85	190
		HFC	85	210
		CC	-	250
		GC	-	230
GL	-	FFC	85	200
		FWC	85	210
		FWCC	85	200
		HFC	85	230
		HFCX	100	210
		CC	-	220
		GC	-	230

Note.- CL and CC: Control boards from commercial pulps.
GL and GC: Commercial boards.

Discussion of Combining Operations

The following comments are essentially those of R. Nelson, superintendent of the Gair Company. It is his opinion that all of the Florida bagasse corrugating media could be run successfully on commercial corrugating machines. He also believes that the test liner board was equal to or better than the material that he was using with the single exception of the 100-percent bagasse liner (FFLX).

The Hawaiian bagasse corrugating media (HFC and HFCX) produced an exceptionally strong flute which was superior to the material they were currently using. It may be that the corrugations were too stiff for industrial use and were better than that required. The test liner board was equal to their material when run on the corrugator; however, when combined with the excessively strong corrugating medium, splits were noticed along the score lines. This splitting was in all probability due to the stiffness of the corrugating medium and not to any lack of physical strength in the liner.

To develop optimal strength characteristics for the combined corrugating and liner boards, larger rolls of the same width should be used in combining operations. This would make possible continuous runs at maximum corrugator speeds for longer periods of time. In general, longer runs would provide more opportunity for operational adjustments and consequently would favor production of combined board with better box-forming characteristics and with higher strength values. Nevertheless, the quality and quantity of the experimental corrugating and liner boards were sufficient for development of better than one-half the usual commercial corrugator speed and in some instances a maximum of 320 feet per minute.

The containers on arrival at the laboratory in Peoria were sampled and tested. Sample boxes were selected at random from every third bundle of box flats as received here for this testing and, after conditioning at 73° F. and 50 percent relative humidity, these boxes were tested for Mullen, G. E. puncture test (Beach), and for flat crush. The results grouped by the liner used are given in Table 15 and by the corrugating material used in Table 16. The Mullen test for a combined board is chiefly influenced by the liner and the flat crush test is chiefly influenced by the corrugating medium. The best Mullen test obtained for the combined board was that obtained with the 50-percent bagasse liner board (FFL).

The flat crush test figures show that of the two Florida bagasse corrugating boards (FWC and FFC) made on the Fourdrinier machine, the one made from depithed fiber is better. It should be remembered that in order to run the whole bagasse pulps it was necessary to remove the fines by washing, so this pulp (FWC) was actually more of a chemically depithed bagasse pulp than a whole bagasse pulp. The rather high crush figure obtained for the corrugating board (FWCC) produced on the cylinder machine is due primarily

Table 15.--Physical characteristics of combined experimental, control, and commercial double-face corrugated board arranged to show the effect of the corrugating quality[1]

Combination, code designation	Mullen	G. E. puncture test (Beach)	Flat crush
	lb./sq. in.		lb./sq. in.
FFL-FFC	257	204	71
FFL-FWC	263	191	64
FFL-FWCC	252	205	77
FFL-CC	269	201	56
FFL-GC	253	176	27
HFL-HFC	216	212	64.9
HFL-GC	225	203	32.5
HFL-CC	226	185	51.5
CL-FFC	265	219	77
CL-FWC	260	223	66
CL-FWCC	242	226	77
CL-HFC	253	233	67.8
CL-CC	262	224	63
CL-GC	233	205	27
GL-FFC	242	235	76
GL-FWC	259	233	67
GL-FWCC	244	240	74
GL-HFC	265	232	65.4
GL-HFCX	229	271	87.5
GL-CC	241	228	64
GL-GC	240	203	28
FFLX-GC	197	151	25
FFLY-GC	241	185	25

---

[1] Tests by Northern Division, Peoria, Ill.

Table 16.--Physical characteristics of combined experimental, control, and commercial double-face corrugated board arranged to show the effect of liner quality[1]

Combination, code designation	Mullen	G. E. puncture test (Beach)	Flat crush
	lb./sq. in.		lb./sq. in.
FFL-FFC	257	204	71
CL-FFC	265	219	77
GL-FFC	242	235	76
FFL-FWC	263	191	64
CL-FWC	260	223	66
GL-FWC	259	233	67
FFL-FWCC	252	205	77
CL-FWCC	242	226	77
GL-FWCC	244	240	74
HFL-HFC	216	212	64.9
CL-HFC	253	233	67.8
GL-HFC	265	232	65.4
FFL-CC	269	201	56
HFL-CC	226	185	51.5
CL-CC	262	224	63
GL-CC	241	228	64
FFL-GC	253	176	27
HFL-GC	225	203	32.5
CL-GC	233	205	27
GL-GC	240	203	28
FFLX-GC	197	151	25
FFLY-GC	241	185	25
GL-HFCX	229	271	87.5

---

[1] Tests by Northern Division, Peoria, Ill.

Table 17.--Comparison of top-to-bottom test strengths with calculated strength of C-flute corrugated containers having components made from bagasse fiber. (Tests conducted at 75° F. and 64 percent relative humidity: Box factor = 0.68.)[1]

Code		Combined ring crush of components	Maximum top-to-bottom compression strength of containers		
Liner board	Corrugating medium	Across machine direction	Actual test strength	Calculated strength	Variation of calculated from test strength
		lb./in.	lb.	lb.	%
Single tier, 211 x 414 can box (FJ)					
Florida bagasse					
FFL	FFC	46.0	1,054	985	-7.0
FFL	FWC	47.0	769[2]	1,010	+31.3
FFL	FWCC	45.0	952	960	+0.7
FFL	CC	45.2	621[2]	970	+56.1
FFL	GC	40.9	688[2]	880	+27.9
CL	FFC	41.1	1,020	885	-13.3
CL	FWC	42.1	892	905	+1.5
CL	FWCC	40.1	872	865	-0.8
CL	CC	40.3	1,024	875	-14.6
CL	GC	36.0	522[2]	770	+47.5
GL	FFC	38.4	845	825	-2.3
GL	FWC	39.4	911	850	-6.6
GL	FWCC	37.4	821	800	-2.6
GL	CC	37.6	981	810	-17.4
GL	GC	33.3	648	710	+3.8
FFLX	GC	45.4	604[2]	975	+61.5
FFLY	GC	40.6	675	875	+29.5
Hawaiian bagasse					
GL	HFC	37.7	835	810	-3.0
GL	HFCX	42.9	1,038	920	-11.4
HFL	HFC	50.1	1,076	1,080	+0.5
HFL	GC	45.6	746[2]	975	+30.6
HFL	CC	50.0	872	1,080	+23.9
CL	HFC	40.5	703	875	+24.5
Double tier, 211 x 414 can box (DT)					
GL	HFC	37.7	693	720	+3.9
GL	HFCX	42.9	844	820	-2.8
HFL	HFC	50.1	718[2]	960	+33.6
HFL	GC	45.6	673	870	+29.3
HFL	CC	50.0	697[2]	960	+38.1
CL	HFC	40.5	589	775	+31.5

---

[1] Tests conducted by U. S. Forest Products Laboratory, Madison, Wis.

[2] Poor glue bond was observed between the liners and corrugations.

to the directional nature of the sheet as obtained from the machine. The flat crush test, 87.5 p.s.i. of the combination GL-HFCX, the corrugating medium being from 100 percent depithed Hawaiian bagasse, is an exceptionally high value for 9-point corrugating.

The G. E. puncture test is affected by both the liner and the corrugating board components. The tear of the liner and the flat crush and tear of the corrugating material would appear to be the most important factors affecting the G. E. puncture test. The 50-percent bagasse liner thus leads to a somewhat lower puncture test than the commercial kraft liner but the high flat crush of the bagasse corrugating materials brings the value up somewhat so that a puncture test of a combined board made with 50-percent bagasse liner and a bagasse corrugating board gives results approximately the same as the puncture test of combined board with commercial liner and commercial corrugating board.

EVALUATION OF SHIPPING CONTAINERS

Tests by Forest Products Laboratory

For a number of years the Forest Products Laboratory, U. S. Department of Agriculture Forest Service, Madison, Wis., in cooperation with the Quartermaster Food and Container Institute of the Armed Forces, has been engaged in research studies on shipping containers. One object of this research has been to obtain basic design data for solid fiberboard shipping containers (8).

In the course of its investigations the Forest Products Laboratory had cooperated with a southern board mill and the Northern Division to produce 9-point corrugating from bagasse pulp, to combine the corrugating with liner board, and to evaluate the container board and components thereof. The Syracuse work made available for further evaluation shipping containers comprising 23 combinations of experimental, control, and commercial corrugating and liner boards. The Forest Products Laboratory, therefore, undertook an evaluation of the experimental containers and determined crush resistance of the combined boards as well as the top-to-bottom compressive strengths. Results of these tests together with the calculated compressive strength values are presented in Table 17.

Supplementary comments and interpretations by the Forest Products Laboratory are as follows:

"The compression test values recorded are averages of tests on three boxes. The calculated loads are based on information contained in FPL Report No. R1911-A. Also included in this table are the combined ring crush values for the built-up boards.

These values were determined from ring crush tests of 1/2 x 6-inch specimens cut from the liners and the corrugating medium in the 'across' machine direction. Tests of the components as well as tests of the boxes were conducted on specimens conditioned in an atmosphere maintained at 75° F. and 64 percent relative humidity.

"It has been our experience from previous compression tests of corrugated boxes that the strength of the component parts is related to the strength of the finished box and that the liners and the corrugating medium work together in resisting crushing forces applied to boxes. The proportion of strength contributed by each component part of the board is dependent on the amount of material in each part. For example, the corrugating medium makes up approximately one-third of the material under stress for each unit of column width of the panels of a corrugated box, while the liners make up about two-thirds of the material under stress and, therefore, will be a greater influencing factor than the corrugating medium on container compressive strength.

"Based on the limited number of compression tests of boxes made from bagasse pulps, it appears that the bagasse boxes are stronger in top-to-bottom compression than regular commercial boxes of the same size and having about the same amount of material. This can be accounted for by the fact that the bagasse liners and corrugating mediums are stiffer in edge compression than similar commercial materials. However, this greater stiffness may cause the liner boards to be brittle and thereby reduce rough-handling resistance such as drops. Perhaps when you receive results of some rough-handling tests of these boxes, you will have a more complete basis for comparing bagasse boxes with regular commercial boxes.

"The average box factor for this lot of boxes was approximately 0.68 which is the same factor that was found for regular commercially made boxes. Comparison of calculated compression strengths with actual test strengths show that for the 29 lots, 12 of the calculated strengths were [with, sic] within ±10 percent of actual test strengths. Further, 4 of the calculated strengths were between ±10 percent and ±20 percent, and 13 were greater than ±20 percent of actual test values. The reason for 9 of the 13 calculated values being high could be explained by the fact that these boxes failed prematurely due to a poor glue bond between the liners and the corrugations. Even though a poor glue bond was not apparent in the other 4 sets of boxes it is believed that possibly a weak bond also existed in these boxes."

Tests by Container Laboratories, Inc.

Experimental Containers

G. W. Aljian, Coordinator By-Products Project, Hawaiian Sugar Planters' Association, in accordance with the agreement with the Association, made arrangements for tests to be made by a commercial container-testing laboratory. The Container Laboratories, Inc., San Francisco, Calif., was employed to carry out this work and 920 containers made at Syracuse, N. Y., and representative of the 3 sizes made from each of the 23 different combinations of test liner and corrugating medium, were shipped to that laboratory by the Northern Division.

This company reported as follows:

"Materials Tested. Forty-six different groups of corrugated fibreboard boxes were submitted from the Northern Regional Research Laboratory, Peoria, Illinois, for testing.

"The samples were divided, by size and pulp source, into four categories as follows:

	Florida Combinations		Hawaiian Combinations	
	Flat Juice	Tall Bottles	Flat Juice	Double Tier
Box Size:	16-1/4" x 10-7/8" x 4-7/8"	16-5/8" x 11-3/16" x 8-1/8"	16-1/4" x 10-7/8" x 4-7/8"	10-7/8" x 8-3/16" x 9-7/8"

"Each group was fabricated from a different combination of various component materials. Each group was identified, by the client, with a code symbol.

"All of the boxes bore the 200-lb. test certificate of the Robert Gair Company, Syracuse, New York, were of R. S. C. style with vertical C-flute corrugations, stitched manufacturer's joints and were unprinted except for code symbols. The client stated that all of the boxes were made under experimental conditions.

"The boxes for the revolving drum tests were each packed with 24 water-filled No. 211 x 414 Cylinder Juice cans. The gross weight of each of the packed boxes was approximately 25 lb.

"Performance of Tests. All samples were exposed to a controlled atmosphere of 50 percent relative humidity at 73° F. for 24 hr. following exposure to a lower relative humidity so that moisture content equilibrium could be attained on an absorption basis.

"Top-to-bottom and end-to-end compression tests were made on empty boxes taken from each group. In addition, compression tests were made on designated groups after exposure of the boxes to low relative humidity and to high relative humidity.

"Revolving drum tests were made on designated groups of the flat juice and double tier sizes.

Table 18.--Compression tests made on containers by Container Laboratories, Inc., San Francisco, Calif., showing the effect of individual corrugating mediums used with various liners

(Test conditions: 73° F., 50% R.H.)

Kind of box	Code designation	Compression							Drum test, falls
		Top-to-bottom				End-to-end			
		0.5	0.75	Maximum	Deflection	0.5	Maximum	Deflection	
		lb.	lb.	lb.	in.	lb.	lb.	in.	No.
FJ	FFC-FFL	734	860	934	0.89	628	628	0.42	113.0
TB	FFC-FFL	666	820	926	.84	688	688	.46	-
FJ	FFC-CL	808	844	974	.84	438	438	.30	-
TB	FFC-CL	636	786	802	.77	546	546	.36	-
FJ	FFC-GL	682	891	994	.90	374	374	.42	-
TB	FFC-GL	744	853	875	.72	555	555	.38	-
FJ	FWC-FFL	558	610	656	.78	360	360	.30	82.2
TB	FWC-FFL	634	790	800	.78	548	548	.42	-
FJ	FWC-CL	638	792	1,062	.90	426	426	.32	-
TB	FWC-CL	624	662	674	.71	564	564	.40	-
FJ	FWC-GL	661	689	778	.90	582	582	.42	108.0
TB	FWC-GL	563	664	732	.81	651	654	.50	-
TB	FWCC-FFL	610	696	792	.90	632	670	.52	-
FJ	FWCC-FFL	666	842	906	.85	594	594	.46	-
FJ	FWCC-CL	622	630	653	.56	468	468	.30	-
TB	FWCC-CL	597	701	749	.71	623	623	.40	-
FJ	FWCC-GL	605	838	934	.78	514	514	.38	124.2
TB	FWCC-GL	644	805	805	.70	610	610	.44	-
FJ	HFC-GL	502	728	1,083	.90	632	632	.50	122.0
DT	HFC-GL	406	574	699	.86	492	492	.36	82.8
FJ	HFC-HFL	738	876	1,188	.92	717	717	.42	62.6
DT	HFC-HFL	487	666	759	.86	573	573	.36	73.0
FJ	HFCX-GL	589	731	1,212	.90	641	641	.42	143.8
DT	HFCX-GL	443	776	931	.84	549	549	.38	87.6
FJ	CC-FFL	556	642	872	.90	640	640	.48	-
TB	CC-FFL	508	758	1,014	.92	654	680	.50	-
FJ	CC-HFL	463	543	913	1.18	537	537	.34	54.4
DT	CC-HFL	384	488	654	.90	480	480	.38	67.2
FJ	CC-CL	524	660	1,034	1.00	528	528	.46	124.8
TB	CC-CL	484	620	986	1.00	570	610	.52	-
FJ	CC-GL	561	774	1,038	.92	595	595	.46	93.2
TB	CC-GL	569	685	1,078	1.02	588	588	.38	-
FJ	GC-FFL	482	582	582	0.64	488	488	.42	55.8
TB	GC-FFL	556	646	688	.86	442	442	.50	-
FJ	GC-FFLX	392	530	688	1.18	410	410	.32	29.4
TB	GC-FFLX	450	616	625	0.68	380	380	.38	-
FJ	GC-FFLY	514	664	722	.88	420	420	.38	71.8
TB	GC-FFLY	524	592	634	.81	402	402	.34	-
FJ	GC-HFL	539	677	840	.90	590	590	.38	72.2
DT	GC-HFL	380	646	677	.82	464	464	.34	57.8
FJ	GC-CL	486	634	804	.90	412	412	.38	125.8
TB	GC-CL	474	530	608	.86	422	422	.40	-
FJ	GC-GL	470	667	839	.86	390	390	.34	86.0
TB	GC-GL	451	560	741	.90	460	460	.38	-

"For the high-humidity tests, the knocked-down boxes were conditioned at 80 percent relative humidity and 73° F. for 48 hr. The boxes were then set up, conditioned for another 24 hr. in the same atmosphere, and then tested.

"For the low-humidity tests, the knocked-down samples were first preconditioned in an atmosphere of 25 percent relative humidity and 90° F. The samples were then placed in an atmosphere of 35 percent relative humidity and 85° F. for 48 hr., set up, conditioned for an additional 24 hr., and tested.

"In the 7-foot revolving drum test, the packed boxes were tested individually until failure occurred. Failure was defined as the appearance of one or more of the following conditions.

1. Complete rupture of any score
2. Spillage of cans
3. Leaking cans

"The revolving drum tests were made with the pointed hazard in place.

"Synopsis. Compression tests were made on boxes conditioned at low, standard, and high humidity. Revolving drum tests were made on packed boxes conditioned at standard humidity.

"In the 'flat juice' and 'tall bottle' box sizes, there were four groups fabricated from 'commercial' components. If the results on these groups are taken as a reference standard, the following general conclusions are indicated by the test results:

"For the 'flat juice' and 'tall bottle' sizes, only -

1. Considering the results obtained from the low, standard and high humidity compression tests, approximately 75 percent of the bagasse groups were equal to, or better than the comparable 'commercial' groups.

2. In the revolving drum tests approximately 50 percent of the bagasse groups were equal to, or better than, the comparable 'commercial' groups.

"Fabrication Defects. Almost all of the groups tested had serious and extensive fabrication defects. These defects included poor stitching at the manufacturer's joint, areas of no adhesion, poor adhesive bond, high-low corrugations, poor fit of cans, and others.

"Since the defects were so widely and uniformly distributed it is doubtful that any one group had an advantage over any other in this regard. Any one of the combinations could be expected to perform better if the defects were reduced or eliminated."

Summaries of the test data obtained by the Container Laboratories, Inc., are presented in Tables 18-20. These data were obtained in tests conducted at 73° F. and 50 percent relative humidity.

Table 19.--Results of compression and drum tests on shipping containers fabricated at Syracuse, N. Y., from experimental, control, and commercial container boards,[1] ("a" denotes acceptable test, i.e., values meet specifications)

(Test conditions: 73° F., 50% R.H.)

Code designation	Compression End-to-end maximum	 Top-to-bottom maximum	Drum test, falls
	lb.	lb.	No.
Single tier, style (FJ) specifications:		Top-to-bottom, 794 lb. End-to-end, 575 lb.	
HFC-HFL	717a	1,188a	62.6
HFCX-GL	641a	1,212a	143.8
HFC-GL	632a	1,083a	122.0
CC-FFL	640a	872a	-
FFC-FFL	628a	934a	113.0
FWCC-FFL	594a	906a	-
CC-GL	595a	1,038a	93.2
GC-HFL	590a	840a	72.2
FWC-GL	582a	778	108.0
FWC-CL	426	1,062a	-
CC-CL	528	1,034a	124.8
FFC-GL	374	994a	-
FFC-CL	438	974a	-
FWCC-GL	514	934a	124.2
CC-HFL	537	913a	54.4
HFC-CL	558	895a	128.8
GC-GL	390	839a	86.0
GC-CL	412	804a	125.8
GC-FFLY	420	722	71.8
FWC-FFL	360	656	82.2
GC-FFLX	410	688	29.4
FWCC-GL	468	653	-
GC-FFL	488	582	55.8

--Continued

Table 19.--(continued)

Code designation	Compression		Drum test, falls
	End-to-end maximum	Top-to-bottom maximum	
	lb.	lb.	No.
Tall bottle, style (TB) specifications:		Top-to-bottom, 762 lb. End-to-end, 693 lb.	
CC-GL	588	1,078a	
CC-FFL	680	1,014a	
CC-CL	610	986a	
FFC-FFL	688	926a	
FFC-GL	555	875a	
FWCC-GL	610	805a	
FFC-CL	546	802a	
FWC-FFL	548	800a	
FWCC-FFL	670	792a	
FWCC-CL	623	749	
GC-GL	460	741	
FWC-GL	654	732	
GC-FFL	442	688	
FWC-CL	564	674	
GC-FFLY	402	634	
GC-FFLX	380	626	
GC-CL	422	608	
Double tier, style (DT) specifications:		Top-to-bottom, 610 lb. End-to-end, 646 lb.	
HFCX-GL	549	931a	87.6
HFC-HFL	573	759a	73.0
HFC-GL	492	699a	82.8
GC-HFL	464	677a	57.8
HFC-CL	431	656a	71.4
CC-HFL	480	654a	67.2

---

[1] Tests conducted by Container Laboratories, Inc., San Francisco, Calif.

Table 20.--Results of drum and compression tests on single tier style shipping containers fabricated at Syracuse, N. Y., from experimental, control, and commercial materials.[1] (Arranged in descending order of number of falls in drum tests.)

(Test conditions: 73° F., 50% R.H)

Code designation	Drum test, falls	Compression tests						
		Top-to-bottom				End-to-end		
		0.5	0.75	Maximum	Deflection	0.5	Maximum	Deflection
	No.	lb.	lb.	lb.	in.	lb.	lb.	in.
HFCX-GL	143.8	589	731	1,212	0.90	641	641	0.42
GC-CL	125.8	486	634	804	.90	412	412	.38
CC-CL	124.8	524	660	1,034	1.00	528	528	.46
FWCC-GL	124.2	605	838	934	0.78	514	514	.38
HFC-GL	122.0	502	728	1,083	.90	632	632	.50
FFC-FFL	113.0	734	860	934	.89	628	628	.42
FWC-GL	108.0	661	689	778	.90	582	582	.42
CC-GL	93.2	561	774	1,038	.92	595	595	.46
GC-GL	86.0	470	667	839	.86	390	390	.34
FWC-FFL	82.2	558	610	656	.78	360	360	.30
GC-HFL	72.2	539	677	840	.90	590	590	.38
GC-FFLY	71.8	514	664	722	.88	420	420	.38
HFC-HFL	62.6	738	876	1,188	.92	717	717	.42
GC-FFL	55.8	482	582	582	.64	488	488	.42
GC-FFLX	29.4	392	530	688	1.18	410	410	.39

---

[1] Tests conducted by Container Laboratories, Inc., San Francisco, Calif.

Results of top-to-bottom, end-to-end compression tests, and the drum tests data on the cartons are reported in Table 18. The test results are grouped according to the corrugating medium of the containers. Container Laboratories, Inc. conclude for the "flat juice" and "tall bottle" sizes only that considering the results obtained from the low-, standard, and high-humidity compression tests, approximately 75 percent of the bagasse group is equal to or better than comparable "commercial" groups.

In Table 19, the data are arranged in groups of shipping containers for which the "flat juice" or "tall bottle" types of cartons meet or fail to meet end-to-end and top-to-bottom standards of compression.

Only nine of the containers met quality standards for both end-to-end and top-to-bottom compression. Nine more met only the top-to-bottom standard and the commercial Gair Company cartons, GC-GL, had the lowest test of this group.

In the "tall bottle" series none met both compression standards. Nine of these met the top-to-bottom standard compression value. The GC-GL container failed to meet either standard. Ten of the total lot of containers tested higher in top-to-bottom compression and 13 out of the 17 in the series tested higher in end-to-end compression.

In the "double tier" series all containers met the top-to-bottom compression standard; none the end-to-end standard. The Gair Company box GC-GL was not made in this style.

Results of drum and compression tests by Container Laboratories, Inc., on "flat juice" style shipping containers arranged in descending order of the number of falls of the containers are shown in Table 20. In the drum tests, eight of the experimental combinations rated higher than the combination of commercial boards GC-GL; six were lower than GC-GL.

Comparative characteristics of boxes and test liner fabricated from control corrugating and liner boards produced from commercial materials under the experimental conditions at Syracuse and from commercial test liner are presented in Table 21. The tests were performed by Container Laboratories, Inc., and the Northern Division. The containers made from the control boards had characteristics slightly superior to those of containers made from commercial test liner. These results indicate satisfactory operation of the paper machine at the College of Forestry.

The effects of the various corrugating media on container tests are shown by data presented in Table 22. These results show superiority in all respects of both Florida and Hawaiian bagasse (85 percent and 15 percent corrugating waste) for the making of corrugating medium over other media made of 85 percent semichemical

Table 21.--Comparative physical characteristics of single tier style containers fabricated at Syracuse, N. Y., from commercial corrugating and liner boards and from control boards made from commercial pulps at the College of Forestry

(Test conditions: 73° F., 50% R.H.)

Liner material	Corrugating material	Top-to-bottom maximum compression[1]	Drum test,[1] falls	Mullen[2]	G. E. puncture[2] (Beach)	Flat crush[2]
		lb.	No.	p.s.i.		p.s.i.
Commercial GL	Commercial (waste paper) GC	839	86	240	203	25
Commercial GL	Control (hardwood semichemical CC	1,038	93.2	241	228	63
Control (softwood kraft) CL	Commercial (waste paper) GC	804	125.8	233	203	28
Control (softwood kraft) CL	Control (hardwood semichemical CC	1,034	124.8	262	224	63

[1] Tests performed by Container Laboratories, Inc., San Francisco, Calif.

[2] Tests performed by Northern Division, Peoria, Ill.

Table 22.--Summary of physical characteristics of experimental shipping containers (single tier style) fabricated at Syracuse, N. Y., arranged to show the effect of corrugating composition on the quality of the containers

(Test conditions: 73° F., 50% R.H.)

Code designation	Corrugating material	Top-to-bottom maximum compression[1]	Drum test[1] falls	Mullen[2]	G. E. puncture[2] (Beach)	Flat crush[2]
		lb.	No.	p.s.i.		p.s.i.
GL-HFCX	100% Hawaiian bagasse	1,212	143.8	229	271	87.5
GL-HFC	85% Hawaiian bagasse	1,083	122.6	265	232	65
GL-FFC	85% Florida bagasse	994	-	242	235	76
GL-FWCC	85% Florida bagasse cylinder	934	124.2	244	240	74
GL-FWC	85% Florida bagasse	778	108.0	259	233	67
GL-CC	Control (hardwood semichemical)	1,038	93.2	241	228	64
GL-GC	Commercial (waste paper)	839	86.0	240	203	28
CL-HFC	85% Hawaiian bagasse	895	128.8	253	233	68
CL-FFC	85% Florida bagasse	974	-	265	219	77
CL-FWCC	85% Florida bagasse cylinder	653	-	242	226	77
CL-FWC	85% Florida bagasse	1,062	-	260	223	66
CL-CC	Control (hardwood semichemical)	1,034	124.8	262	224	63
CL-GC	Commercial (waste paper)	804	125.8	233	205	27
FFL-FFC	85% Florida bagasse	934	113.0	257	204	71
FFL-FWCC	85% Florida bagasse cylinder	906	-	252	205	77
FFL-FWC	85% Florida bagasse	656	82.2	263	191	64
FFL-CC	Control (hardwood semichemical)	872	-	269	201	56
FFL-GC	Commercial (waste paper)	582	55.8	253	176	27
HFL-HFC	85% Hawaiian bagasse	1,188	62.6	216	212	65
HFL-CC	Control (hardwood semichemical)	913	54.4	226	185	52
HFL-GC	Commercial (waste paper)	840	72.2	225	203	33

[1] Tests performed by Container Laboratories, Inc., San Francisco, Calif.

[2] Tests performed by Northern Division, Peoria, Ill.

Table 23.--Summary of physical characteristics of experimental shipping containers (single tier style) fabricated at Syracuse, N. Y., arranged to show the effect of liner composition on the quality of the containers

(Test conditions: 73° F , 50% R.H)

Code designation	Liner material	Top-to-bottom maximum compression[1]	Drum test,[1] falls	Mullen[2]	G. E. puncture[2] (Beach)	Flat crush[2]
		lb.	No.	p.s.i.		p.s.i.
CL-GC	Control (softwood kraft)	804	125.8	233	205	27
GL-GC	Commercial kraft	839	86.0	240	203	28
FFLY-GC	25% Florida bagasse	722	71.8	241	185	25
HFL-GC	50% Hawaiian bagasse	840	72.2	225	203	33
FFL-GC	50% Florida bagasse	582	55.8	253	176	27
FFLX-GC	100% Florida bagasse	688	29.4	197	151	25
CL-CC	Control (softwood kraft)	1,034	124.8	262	224	63
GL-CC	Commercial kraft	1,038	93.2	241	228	64
FFL-CC	50% Florida bagasse	872	-	269	201	56
HFL-CC	50% Hawaiian bagasse	913	54.4	226	185	52
CL-FFC	Control (softwood kraft)	974	-	265	219	77
GL-FFC	Commercial kraft	994	-	242	235	76
FFL-FFC	50% Florida bagasse	934	113.0	257	204	71
CL-HFC	Control (softwood kraft)	895	128.8	253	233	68
GL-HFC	Commercial kraft	1,083	122.0	265	232	65
HFL-HFC	50% Hawaiian bagasse	1,188	62.6	216	212	65
CL-FWC	Control (softwood kraft)	1,062	-	260	223	66
GL-FWC	Commercial kraft	778	108.0	259	233	67
FFL-FWC	50% Florida bagasse	656	82.8	263	191	64

---

[1] Tests performed by Container Laboratories, Inc., San Francisco, Calif.

[2] Tests performed by Northern Division, Peoria, Ill.

and 15 percent waste corrugating or 100 percent waste corrugating. The corrugating medium made from 100 percent Hawaiian bagasse was superior to all other media in stiffness, puncture test, and number of falls in the drum.

The effect of raw material on liner board is shown in Table 23. These data indicate that liner board made from bagasse is not equal to liner board made from virgin kraft pulp. As the percentage of bagasse in the liner board increases from 25 percent to 100 percent, the strength properties of the liner board decrease progressively.

A comparison between Florida and Hawaiian bagasse depithed fiber as raw material for making corrugating medium and liner board is shown in Table 24. The Hawaiian fiber appears to be slightly superior in compression tests on combined board. The Hawaiian pulps were cooked to a lesser degree than the Florida fiber although the same amount of chemical was used in pulping bagasse from both sources.

Comparisons of the compression test values obtained by the Forest Products Laboratory and by Container Laboratories, Inc., on container types tested by each are presented in Table 25. In general the test results of the two laboratories are of the same order. The Forest Products Laboratory noted poor adhesion of liner and corrugating medium in some containers and Container Laboratories, Inc., commented also on imperfect container preparation.

Commercial Containers

Drum-test data submitted by Container Laboratories, Inc., had been limited to experimental materials produced at Syracuse and did not involve containers from regular commercial manufacture. In order to establish the performance relationship between the experimental and commercial containers, T. J. Nelson, Assistant Coordinator of the By-Products Project of the Hawaiian Sugar Planters' Association, arranged for further tests by Container Laboratories, Inc. The commercial containers in this instance were those used by the Hawaiian Pineapple Company and the results of the standard drum test are available for comparison with the results obtained from the Syracuse combinations that had been evaluated previously by this same testing laboratory.

The reasons for turning to actual tests rather than existing commercial experience were twofold: First, juice cans were filled with water, whereas each commercial firm tests with their product; and second, the Syracuse cases, being of small size because of the narrow trim at hand, were a relatively unknown quantity in drum testing; drum tests are made generally on the more common sizes of juice can cases, say 24 - 2-1/2's, rather than the small 24/211 juice can case.

Table 24.--Comparative influence of fibers from Florida and Hawaiian bagasse on the physical characteristics of experimental shipping containers fabricated from bagasse, control, and commercial corrugating and liner boards in semicommercial-scale operations at Syracuse, N. Y.

(Test conditions: 73° F., 50% R.H.)

Code designation	Liner	Corrugating	Top-to-bottom maximum compression[1]	Drum test,[1] falls	Mullen[2]	G. E. punc-[2] ture (Beach)	Flat crush[2]
			lb.	No.	p.s.i.		p.s.i.
FFL-GC	50% Florida bagasse	Commercial (waste paper)	582	55.8	253	176	27
HFL-GC	50% Hawaiian bagasse	Commercial (waste paper)	840	72.2	225	203	33
FFL-CC	50% Florida bagasse	Hardwood, semichemical	872	-	269	201	56
HFL-CC	50% Hawaiian bagasse	Hardwood, semichemical	913	54.4	226	185	52
CL-FFC	Control, softwood kraft	85% Florida bagasse	974	-	265	219	77
CL-HFC	Control, softwood	85% Hawaiian bagasse	895	128.8	253	233	68
GL-FFC	Commercial, kraft	85% Florida bagasse	994	-	242	235	76
GL-HFCX	Commercial, kraft	85% Hawaiian bagasse	1,083	122	265	232	65
GL-HFCX	Commercial, kraft	100% Hawaiian bagasse	1,212	143.8	229	271	87.5

---

[1] Test performed by Container Laboratories, Inc., San Francisco, Calif.

[2] Test performed by the Northern Division, Peoria, Ill.

Table 25.--Comparison of maximum top-to-bottom compression values for experimental shipping containers (single and double tier) fabricated at Syracuse, N. Y., as determined by Container Laboratories, Inc., and U. S. Forest Products Laboratory

Composition	U. S. Forest Products Laboratory[1]	Container Laboratories, Inc
	lb.	lb.
	Single tier, 211 x 414 can boxes	
FFL-FFC	1,054[3]	934
FFL-FWC	769[1]	656
FFL-FWCC	952	906
FFL-CC	621[1]	872
FFL-GC	688[1]	582
CL-FFC	1,020	974
CL-FWC	892	1,062
CL-FWCC	872	653
CL-CC	1,024	1,034
CL-GC	522[1]	804
GL-FFC	845	994
GL-FWC	911	778
GL-FWCC	821	934
GL-CC	981	1,038
GL-GC	648	839
FFLY-GC	675[1]	722
FFLX-GC	604[1]	688
GL-HFC	835	1,083
GL-HFCX	1,038	1,212
HFL-HFC	1,076	1,188
HFL-GC	746[1]	840
HFL-CC	872	913
CL-HFC	703	895
	Double tier, 211 x 414 can boxes	
GL-HFC	693	699
GL-HFCX	844	931
HFL-HFC	718[1]	759
HFL-GC	673	677
HFL-CC	697[1]	654
CL-HFC	589	656

---

[1] Test conditions: 73° F., 64% R.H.

[2] Test conditions: 73° F., 50% R.H.

[3] Poor adhesion of liner and corrugating medium.

The tests were conducted by Container Laboratories, Inc., in the same manner as with the experimental cases. Results are as follows:

A pineapple juice case, double-tier style, 200 test board, averaged 114 falls for 5 cases tested.

A pineapple juice case, double-tier style, 275 test board, averaged 178 falls for 5 cases tested.

A pineapple juice case, flat style, 200 test board, averaged 128 falls for 5 cases tested.

The foregoing were "B" flute cases intended for shipment from Hawaii to Mainland markets. The Mullen bursting test standard (e.g., 200 lb.) is no criterion for drum test durability. In fact, general doubts about the bursting or puncture test exist, which is one reason the drum refalling test was injected into the picture of Syracuse cases.

Ten sample cases such as might be used for domestic Mainland marketing of these juice cans were also run. These 200 test cases, also "B" flute board and double-tier style, averaged 32 falls.

A comparison of these data with the full report rendered by Container Laboratories, Inc., on the Syracuse-made cases, gives rise both to optimism and doubt regarding data on some of the bagasse combinations. On the one hand, the Syracuse cases almost all held together longer than 32 falls before failure. On the other hand, the loose fill of the Syracuse cases, which had resulted in widespread can denting, may have lengthened rather than shortened the case life. The container laboratory points out that, for what it may mean, the Syracuse boxes were "C" flute and the commercial cases "B" flute. Also, the 32-fall local case was made with cylinder board liners, which tear or cut easily on the horizontal score lines of the cases. Liners in the experimental cases had been made on a Fourdrinier machine.

However, subject to all such limitations inherent in the data, Container Laboratories, Inc., consider that the drum-test comparisons, overall, certainly lend encouragement to the 9-point picture on bagasse.

Commercial Evaluation in Rail and Truck Shipments

The Pabst Brewing Company, Milwaukee, Wis., and Libby, McNeill and Libby, Chicago, Ill., cooperated with the Northern Division by providing their facilities and services for evaluation of the experimental containers in practical shipping tests.

Tests by Pabst Brewing Company

The Pabst Brewing Company conducted a rail shipping test with the experimental containers to evaluate their utility and practicality in handling canned and bottled goods. One hundred twenty experimental containers for cans and bottles were loaded and placed in a boxcar together with 2,550 regular can containers and 1,835 regular bottle containers. The experimental containers were distributed throughout the car in a random manner from end to end to make a representative test. On arrival at destination the containers were examined. The shipment contained 14 broken bottles, all of which were in regular containers. Considering the number of cartons involved, this might be due to weaknesses in the bottles and have no bearing on the quality of the cartons. Representatives of the Pabst Brewing Company indicated the containers on the whole were in good condition. In their remarks concerning the condition of the individual containers, the most common defects were loose top and bottom flaps, slight creases, and buckling of a few of the cartons. The tops of these containers were glued and the bottoms stapled; in a few instances the latter were loosened in shipment. The loosening of the top and bottom resulted in lower ratings in the general condition of the containers. Creasing and buckling were most noticeable in the experimental bottle containers. The experimental can containers were rated somewhat higher, as the loosening of the top and bottom apparently did not result in as much damage as when the box contents were bottles. Men examining the shipment stated there was no damage to the cans. The conditions of the special group were good to excellent in most instances. Results of this shipping test under commercial conditions are presented in Table 26.

Mr. Weiner, vice-president of Pabst Brewing Company, pointed out that the corrugating medium used in the experimental containers was of a heavier (10 percent) basis weight than that used in their commercial containers. Because of the reasonably good condition of the containers no photographs were taken of the containers, as it appeared no purpose would be served in the added work involved. In a summary of the condition of the containers it was indicated that the all-bagasse liner provided the poorest group of containers investigated in this test. This same group rated rather poorly in the drum drop test presented previously in Table 20. The shipping tests carried out by Pabst Brewing Company agreed rather well with laboratory-predicted performance, and although the test was rather limited in number of containers of any one group, observations were based on a careful examination of each container involved in the test.

Tests by Libby, McNeill and Libby

Libby, McNeill and Libby conducted combination rail-and-truck shipping and warehousing tests to determine durability of the experimental shipping containers under actual field conditions.

Table 26.--Condition of experimental shipping containers and contents following railway shipping test conducted by Pabst Brewing Company, Milwaukee, Wis.

Composition of container	Number of containers used in tests		Bottles or cans broken		General condition of can containers				General condition of bottle containers			
	Cans	Bottles	Cans	Bottles	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
FFL-GC	4	5	0	0		4				5		
FFLX-GC	5	5	0	0			4	1		2	3	
FFLX-GC (control)	5	6	0	0	5					5	1	
GL-GC	5	5	0	0	5					4	1	
CL-FFC	5	5	0	0	2	3				3	2	
CL-FWC	5	5	0	0	5				2	3		
CL-FWCC	5	5	0	0		4	1			2	2	1
FFL-FWC	5	5	0	0	1	4			1	3	1	
FFL-FWCC	5	5	0	0		5			1	2	2	
CL-HFC	5	-	0	-	5							
GL-HFC	5	-	0	-		5						
GL-HFCX	5	-	0	-	5							
HFL-CC	5	-	0	-	5							
HFL-HFC	5	-	0	-		4	1					
FFL-FFC	5	-	0	-	5							

L. M. Quanstrom, of the purchasing department supervised these tests. The experimental containers were shipped to the Company's Hammond, Ind., warehouse where they were packed and readied for shipment. Five hundred containers representing 10 combinations of corrugating and liner boards were involved. Four of the groups contained boards prepared from Hawaiian bagasse and 5 from Florida bagasse; the tenth contained boards from the commercial operations at the Robert Gair plant in Syracuse. This last group served as a control. The following list includes the boxes used in this shipping test:

Two-Tier Containers

1. GL-HFC
2. GL-HFCX
3. HFL-HFC
4. HFL-CC

Single-Tier Containers

1. FFL-FFC
2. FFL-FWC
3. FFL-CC
4. FFLY-GC
5. GL-FFC
6. GL-GC

The containers were packed with 211 x 414 cans and loaded in railroad cars along with the regular Libby, McNeill and Libby shipments for transportation to the Pittsburgh, Pa., warehouse. On arrival the containers were stacked in storage for several days and then returned to the Hammond, Ind., plant by truck with some of the Company's standard containers included as a control. This was considered a normal shipment, equal in hazards to what might be expected of usual shipments. Representatives of the Northern Division and of Libby, McNeill and Libby were present to observe the condition of the containers on their return to Hammond.

Minor damage to some of the containers occurred in all of the groups, but the amount of damage was average or possibly less than that incurred by commercial containers made in accordance with company shipping specifications.

The containers made from the commercial boxboard, GL-GC, showed a greater tendency toward vertical creasing than the experimental containers made from bagasse, possibly because the combined board of the control container was slightly softer than that of the bagasse container. Horizontal creasing of the boxboard container due to impact with a rather sharp edge resulted in bending of the cans adjacent to that side of the container. This was a normal condition. There were a few breaks in the liner on the horizontal scores which did not seem to result in damage to the cans. There was evidence of marks horizontally arranged on some of the containers where apparently the shipment had "sawtoothed" in the rail car; in these the cans were dented in an amount normal to company standard kraft containers.

Although no inferiority in performance was exhibited by the bagasse-containing boxes, it was Mr. Quanstrom's opinion that a certain brittle stiffness existed and that this brittleness might develop weaknesses in the horizontal scoring if the containers were subjected to more drastic handling.

SUMMARY

Sugarcane bagasse, because of its annual availability in large concentrations at sugar mills, has been for many years an inviting source of raw material for use in pulping and papermaking. Recent development of practicable methods for separation of pith from bagasse fiber has removed the major deterrent to economical and effective pulping, and has increased the attractiveness of this crop residue for commercial utilization in the production of 9-point corrugating and 16-point liner boards for use in shipping containers.

To determine the technical feasibility of using sugarcane bagasse for the production of container boards, the Northern Regional Research Laboratory, with the cooperation of the Hawaiian Sugar Planters' Association, initiated and completed a broad research program involving pulping and board-making investigations on laboratory, pilot-plant, and semicommercial scales. The semicommercial-scale activities were carried out under contract by the College of Forestry of the State University of New York. These activities, involving both cylinder and Fourdrinier wet-end machines, resulted in the production of 9-point corrugating and 16-point liner boards in 40-inch trim from mechano-chemical soda pulps of Florida and Hawaiian bagasse and bagasse fiber. Boards for comparative and control purposes were prepared from commercial wood pulps. Nine bagasse boards and two wood boards were produced. These were processed in a commercial corrugating plant to prepare container boards of 23 combinations of liner and corrugating. The container boards were fabricated into about 12,000 can and bottle shipping containers. Both laboratory container tests and commercial truck and rail shipping tests were made with these containers as well as with commercial containers of the same size and loading.

Results of this investigation conducted through semicommercial-scale operations demonstrate, from the standpoint of technology, the practical utility of producing corrugated shipping containers from sugarcane bagasse, preferably depithed fiber, such containers having properties comparable to or surpassing those of presently used commercial containers of the same test group.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and cooperation of the personnel of the several organizations without whose help accomplishment of the objectives would have been impossible; of the Hawaiian Sugar Planters' Association and the United States Sugar Corporation in providing bagasse and bagasse fiber for these investigations; of the Robert Gair Co., in fabricating containers from the experimental boards; and of the U. S. Forest Products Laboratory, Libby, McNeill and Libby, the Pabst Brewing Company, and the Container Laboratories, Inc., for tests and evaluations of the fabricated containers.

LITERATURE CITED

1. Anonymous
   1956. Sees corrugated board output increasing 40% by 1965. Paper Mill News 79 (50): 22, December 15.

2. Aronovsky, S. I. and Lathrop, E C.
   1949. A new Mechano-Chemical Process for pulping agricultural residues. TAPPI 32 (4): 145-149, April.

3. ______________ and ______________
   1955. Process for pulping. U. S. Patent 2,708,160 (Issued May 10.)

4. ______________, Nelson, G. H., and Lathrop, E. C
   1943. Agricultural residue pulps - bleaching studies on straw pulps. Paper Trade J. 117 (25): 38-48, December 16.

5. ______________, Younger, S. O., and Nelson, G. H.
   1945. Agricultural residue pulps for corrugating. Effects of weathering and of various cooking conditions. Paper Trade J. 120 (8): 124, 126, 128, 130, 132, February 22.

6. Atchison, Joseph E.
   1952. Review of the Commercial Attempts to Use Bagasse as a Papermaking Material, Appendix F of Study of Newsprint Expansion, A Progress Report of the Department of Commerce to Subcommittee No. 5 of the Committee on the Judiciary, House of Representatives, 82nd Congress, 2nd Session.

7. Keller, Arthur G.
   1956. Economical bagasse separation. Sugar J. 18 (10): 16-17, 20, March.

8. Kellicutt, K. Q. and Landt, E. F.
   1953. Basic Design Data for Solid Shipping Containers, Forest Prod. Res. Soc., Seventh Ann. Meeting, New York State College of Forestry, No. 246.

9. Krancher, Carl G. and Price, Carl E.
   1950. Hydrapulper processing of straw. TAPPI 33 (6): 275-277, June.

10. Lathrop, E. C.
1930. The Celotex and cane-sugar industries. Bagasse or sugar a by-product? Ind. Eng. Chem. 22: 449, May.

11. _______________
1947. The industrial utilization of sugar cane bagasse. The Sugar J. 10 (6): 5-7, 19, 30, November.

12. _______________ and Aronovsky, S. I.
1954. The contributions that sugarcane bagasse can make to the paper and board industries. TAPPI 37 (12): 24A, 26A, 28A, 30A, 32A, 34A, 38A, 40A, 42A, 44A, 46A, 48A, 50A, 52A, 54A, 56A, 58A, December.

or:

U. S. Dept. Agr., Agr. Res. Service. Northern Utilization Research Branch ARS-71-1. 22 pp. /Processed/ November.

13. _______________, Naffziger, T. R., and Mahon, H. I.
1955. Methods for separating pith-bearing plants into fiber and pith. U. S. Dept. Agr., Agr. Res. Service. Northern Utilization Research Branch ARS-71-4.

14. Reid, J. D., Nelson, G. H., and Aronovsky, S. I.
1940. Determination of cellulose in fibrous agricultural waste. Ind. Eng. Chem. 12: 255-259, May 15.

15. Technical Association of the Pulp and Paper Industry. TAPPI Standards and Suggested Methods. Tentative and Official Testing Methods--Recommended Practices--Specifications.